ISIS

INDIVIDUALIZED SCIENCE INSTRUCTIONAL SYSTEM

SOUNDS OF MUSIC

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SOUNDS OF MUSIC

ANNOTATED TEACHER'S EDITION

Ginn and Company

The work presented or reported herein was supported by a grant from the National Science Foundation. However, the opinions expressed herein do not necessarily reflect the position or policy of the National Science Foundation, and no official endorsement by that agency should be inferred.

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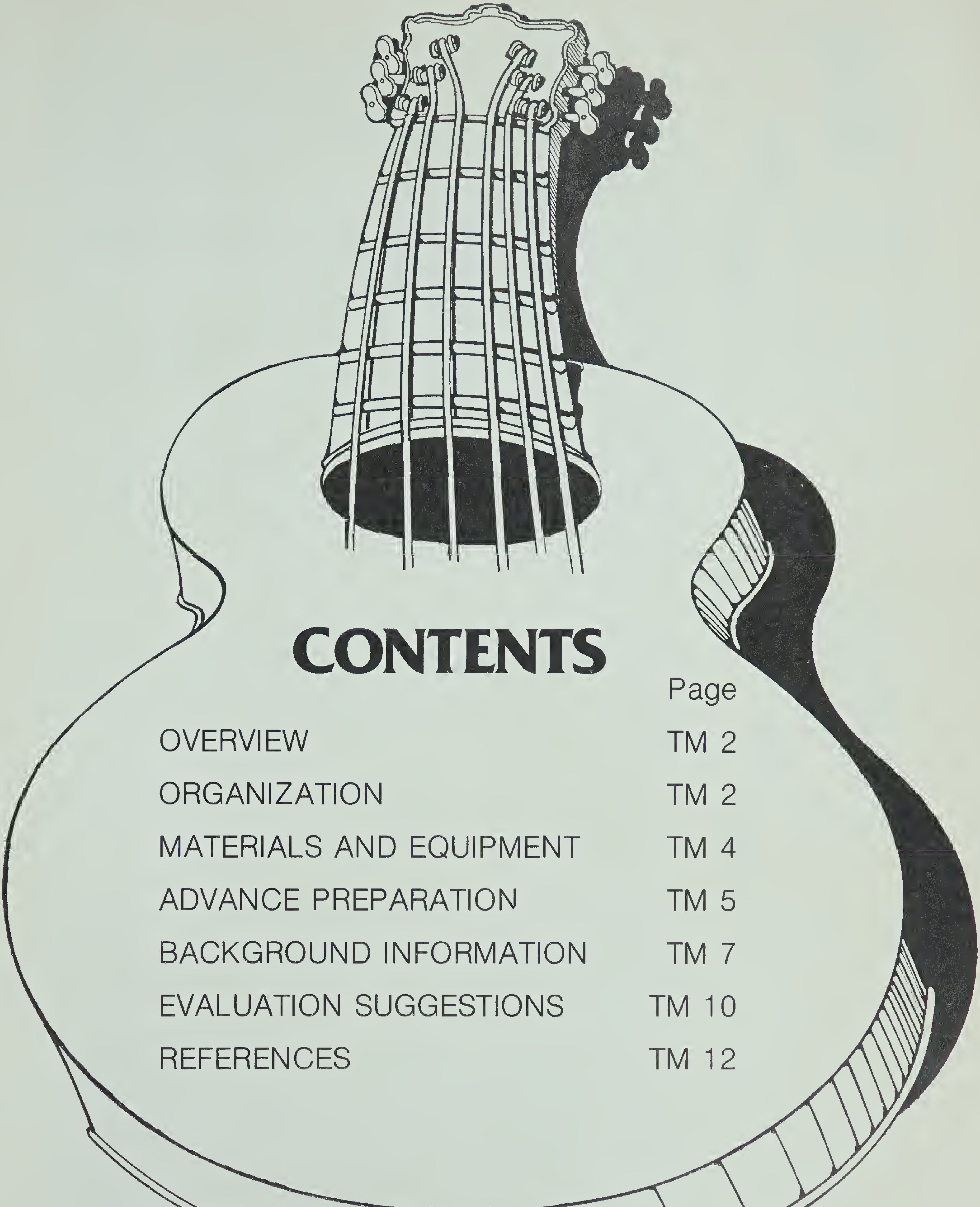


CONTENTS

Sounds of Music introduces students to some basic understandings about sound. The minicourse utilizes the high school student's strong involvement with music to deal with topics such as the nature of sound, how sounds are produced and transmitted, how we hear sounds, how musical instruments work, how to buy sound equipment, musical relationships, and the impact of noise on our lives. Although these topics touch upon a number of disciplines—physics, anatomy, musicology, environmental science, and even consumer education—the main thrust of the minicourse is on sound as a physical phenomenon.

Sounds of Music can be used effectively in a general science program. The physics topics can serve as a starting point for further study by science-motivated students. For example, this minicourse provides a practical introduction to a study of wave motion.

Because musical instruments are the focus of a number of activities exploring the physics of sound, this minicourse might also be used in a music course with students who may have little contact with science.

Sounds of Music contains eleven activities in the core section, four in the advanced section, and three in the excursion section. In each section, the planning activity must be done first. These are some additional restrictions on the order in which core activities may be done:

1. Activity 2 should be done immediately after the planning activity, followed by Activity 3.
2. Activity 7 should be done before Activity 8 or 9.

These restrictions only suggest the prerequisite knowledge required for certain activities in the core. There is no implication that all students must do all prerequisite activities. Students should be encouraged to skip these prerequisite activities if they feel that they already know the material.

With the exception of an activity on the purchase of sound equipment, the core activities focus on the nature of sound, sound production, and sound transmission in situations relevant to students. These activities deal with sound waves, music and noise, overtones, the production of sounds by the human voice and by various types of musical instruments, and the anatomy of hearing. The emphasis in the core is on the physics of sounds rather than on the art of music.

In the advanced activities, students are introduced to the quantitative relationship between frequency and wavelength and to the characteristics of musical notes as they relate to wave motion. Students learn the use and function of the oscilloscope. They explore the problem of how octaves, scales, and harmony are related to frequency.

The "sounds of noise" is the theme for an excursion activity dealing with environmental noise. The activity explores how noise is measured, how it affects our lives, and how it can be controlled. Another excursion activity deals with finding the beat in music.

Cassette Tape

The cassette tape for *Sounds of Music* is an integral part of the minicourse. The tape has five bands, accompanying Core Activities 5, 6, and 10, Advanced Activity 15, and Excursion Activity 18.

The tape for *Activity 5: Singing Sounds* deals with how the human voice can be used to produce a wide range of musical sounds. The tape discusses how the human voice is produced, while directing the students to look at the photographs of the larynx in the student booklet. Students are asked to find the highest and lowest pitch they can sing. They learn that the range of the human voice is approximately 60 to 1200 cycles per second.

The tape band for *Activity 6: Hearing Sounds* deals with the wide range of frequencies that people can hear. Students listen to the violin playing four octaves above middle C; they learn that the violin can achieve notes of over 4000 cycles per second. They listen to the bassoon playing three octaves below middle C, and learn that the bassoon can achieve a frequency of about 30 cycles per second. Students listen to the signal generator—a sort of electronic tuning fork capable of producing almost all frequencies without overtones—to determine their own approximate hearing range. They learn that the human ear can hear sounds ranging from about 20 to 20,000 cycles per second.

The tape band for *Activity 10: To Each Its Own Sound* deals with the effect of overtones on the sound of tones of the same frequency. Students listen to the sound of middle A played by six instruments. They hear the differences. They observe the wave pattern of each of these sounds, shown in the student booklet. They learn to identify the overtones, which provide the quality and individuality of each sound.

The tape band for *Activity 15: Octaves, Scales, and Harmony* deals with the relationship between notes within an octave, how

notes are arranged in scales, and how notes are arranged in major chords. Students learn that the scale is the framework on which music is organized. Students refer to the illustration in the student booklet to observe that the smallest musical interval on the piano keyboard is the half step. They learn that there are various types of scales, although the focus of this minicourse is on the major scale. They learn the pattern of the major scale and are introduced to harmony and chords.

The tape band for *Activity 18: And the Beat Goes On . . .* deals with the function of rhythm, or beat, in a song. Students listen to a song in an unaccented version—without a beat—and try to identify the song. They then listen to the same song with an incorrect beat. The tape finally plays the song with the correct beat. Students learn to classify the beat patterns of various musical selections.

The following chart represents an estimate of needs based on "student units." The student unit may be one student working alone, two students working as partners, or several students working as a group. The size of the student unit will depend on the nature of the activity and on the availability of materials and equipment.

QUANTITY PER STUDENT UNIT	ITEMS	ACTIVITIES			NO. UNITS THAT CAN SHARE
		Core	Advanced	Excursion	
	Consumable				
3	* Rubber bands (two of the same length, one thick, one thin)	9			
2	Soda straws, plastic	8			
	Nonconsumable				
1	Beaker, 250 ml	2			10
1	* Bottle, soft drink, empty	7			10
1	* Bicycle or comb	3			15
1	* Card, stiff	3			15
1	Cassette tape for *Sounds of Music*	5, 6, 10	15	18	10
1	* Cassette tape player, preferably with earphones	5, 6, 10	15	18	10

* Items that can be obtained locally.

Materials and Equipment (Continued)

QUANTITY PER STUDENT UNIT	ITEMS	ACTIVITIES			NO. UNITS THAT CAN SHARE
		Core	Advanced	Excursion	
	Nonconsumable				
1	* Guitar, violin, or piano (optional)	9			15
1	Metric ruler, 30 cm	8, 9			5
1	* Microphone (optional)		14		15
1	* Oscilloscope (optional)		14		15
1	Rubber striker	2, 3	14		5
1	* Scissors	8			15
1	Tuning fork, 262 cps	3			5
1	Tuning fork, 440 cps	2, 3	14		5
	Resource Unit 9	8			

* Items that can be obtained locally.

Activity 3 Core Page 11

This activity requires the use of a bicycle or bicycle wheel for maximum effectiveness. Because Activities 2 and 3 are prerequisites for the rest of the minicourse, you may find that most students will be doing this activity at the same time. It would be desirable to arrange for a bicycle to be in the classroom for one or two periods so that all students might have access to it when needed.

Activities 7, 8 and 9 Core Pages 29, 34, 38

These activities involve musical instruments. For maximum effectiveness try to obtain actual brass, woodwind, or stringed instruments for classroom use. Some students will be able to bring them from home. Instruments might also be borrowed from the music department.

Activity 11 Core Page 45

Display some advertising leaflets on a variety of sound equipment—tape decks, turntables, speakers, tuners. Most retailers are glad to supply these materials, which should be most useful to

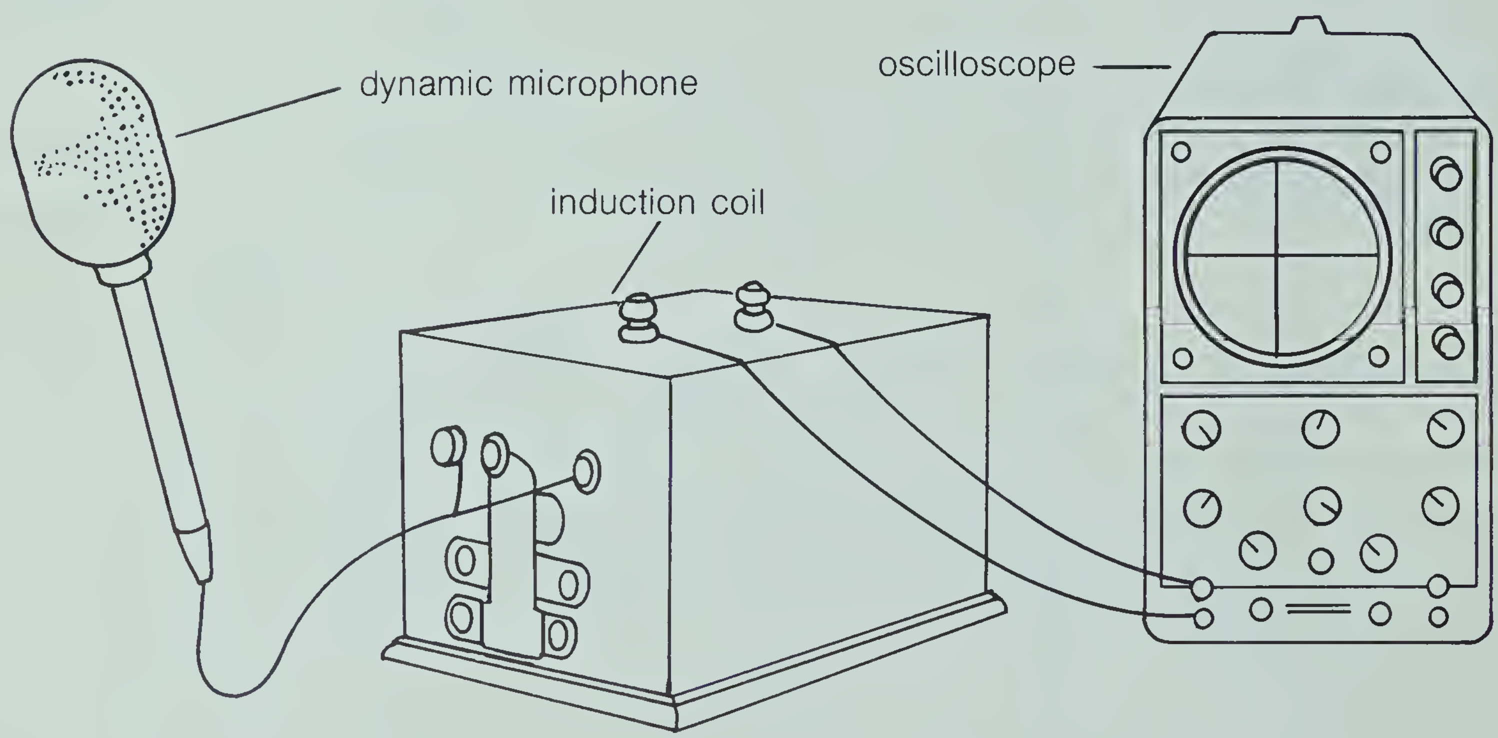
students as they work through the activity. It would also be advantageous to have some recent copies of the Consumer Reports *Buying Guide* and/or some copies of popular hi-fi magazines in the classroom.

Activity 14 Advanced Page 58

Though optional in this activity, the cathode-ray oscilloscope is of great interest to students. If the equipment is available in your school, it is well worth the effort to set it up and keep it adjusted. General information on how to set up and use the oscilloscope is provided in "Background Information," page TM 7. If more specific information is necessary, seek expert help in your school or school district.

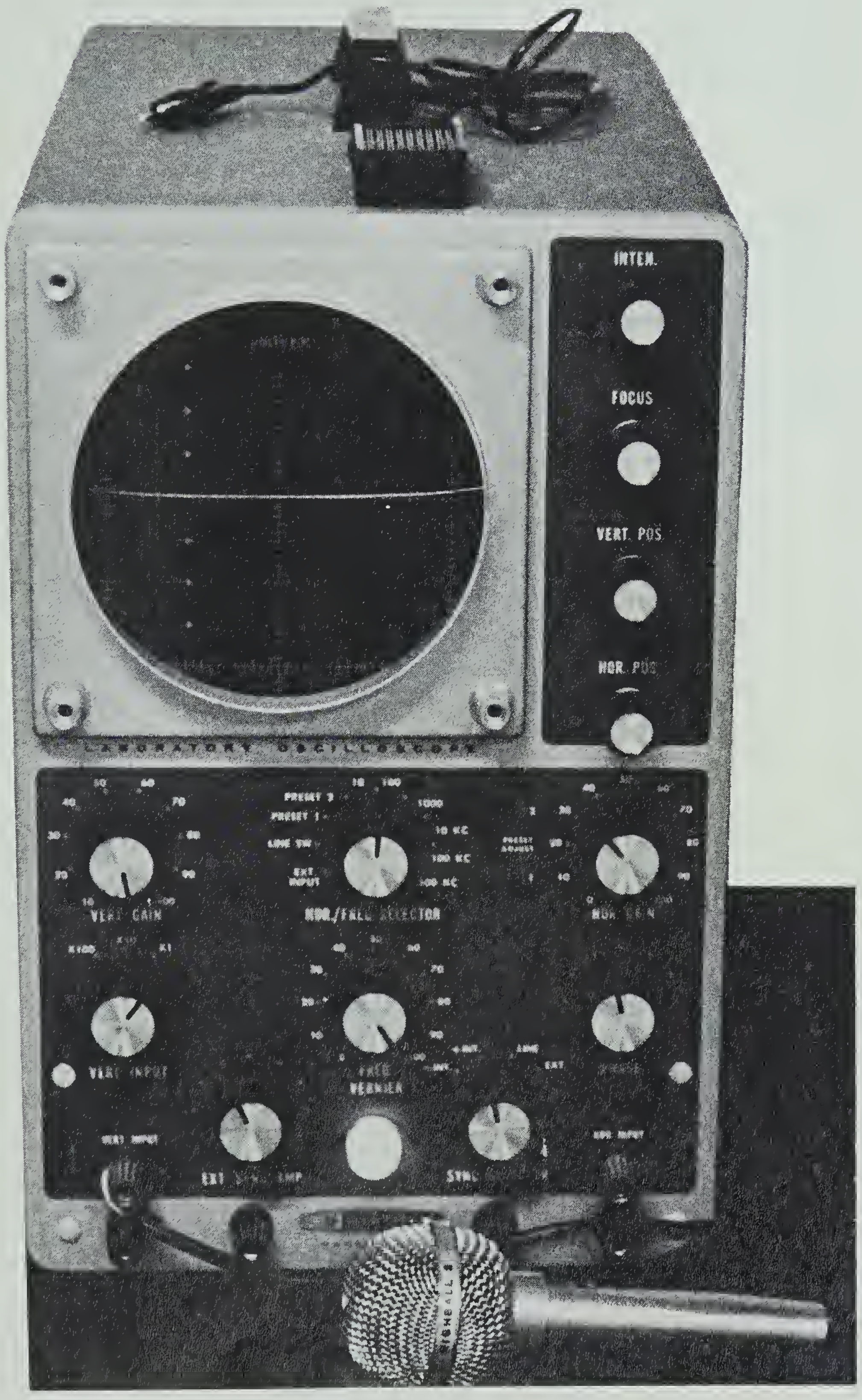
If you have a crystal microphone, you can hook it up directly to the oscilloscope. If you have a dynamic microphone, you will have to feed the signal through an induction coil to step up the voltage. Connect the induction coil to the vertical input terminals of the oscilloscope, as shown in the illustration.

The induction coil you have may not look like the one shown. Instead, the leads may come directly out of the box. If so, be sure that you connect the thick leads to the oscilloscope.



Using the Oscilloscope

The directions provided here are generic and do not refer to any specific model. The positions and names of the controls may vary with different makes and models. If you cannot find a control with the name given here, you may have to experiment to become familiar with the controls. The operating manual for your oscilloscope will provide more specific information.

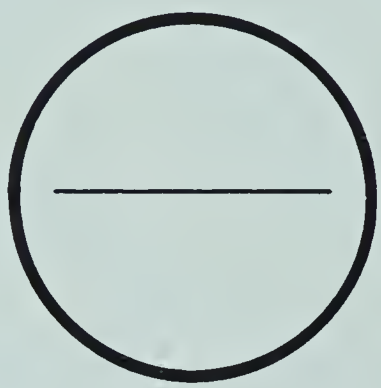


Caution: Never leave the oscilloscope on for any length of time with a bright spot on the screen. This may cause overheating and damage to the instrument.

1. Plug the scope into an electrical outlet and turn it on. (Most oscilloscopes combine the on/off switch with the intensity or brightness control. If the on/off switch and the intensity or brightness indicators are separate, locate the intensity or brightness control and turn it fully counterclockwise.) Wait one minute to allow the scope to warm up. Then turn the intensity up until a spot or trace line is seen. It is important to keep the intensity as low as possible, yet still see the trace line.

2. Locate the controls that shift the position of the trace horizontally (side to side) and vertically (up and down). Center the trace on the screen.

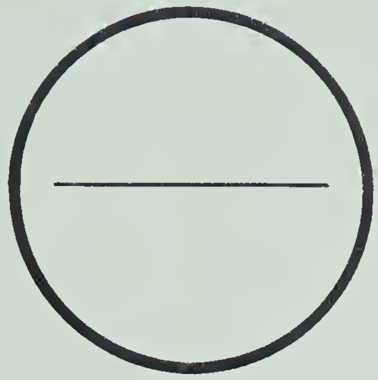
3. Locate the horizontal and vertical gain controls. Turn the vertical gain until the trace is a single, horizontal line, as shown.



4. Turn the horizontal gain until this line becomes a spot. Recenter the spot using the horizontal and vertical position controls.

5. Locate the position of the focus control. Adjust it to get the smallest spot possible.

6. Increase the horizontal gain until the spot becomes a line that nearly crosses the screen.



7. Locate the vertical input terminals. These are normally a pair of terminals labeled either "+" and "—" or "+" and "ground." Attach a short wire to the + terminals and leave the other end free. Turn up the vertical gain until a vertical pattern is seen on the screen.

8. Many scopes have a control for vertical range or vertical input. This will control the size of the signal that can be made to fill the screen. Using this and the vertical gain controls, adjust the trace until it almost reaches the top and bottom of the screen. The pattern should look like that shown.

9. If the scope has a sweep-time control, set it at 1/100 second. The trace should then appear to be standing still, not shifting from side to side. Sideward shifting can be stopped by adjusting the sync. (for synchronization) control (sometimes called the sync. amplitude).

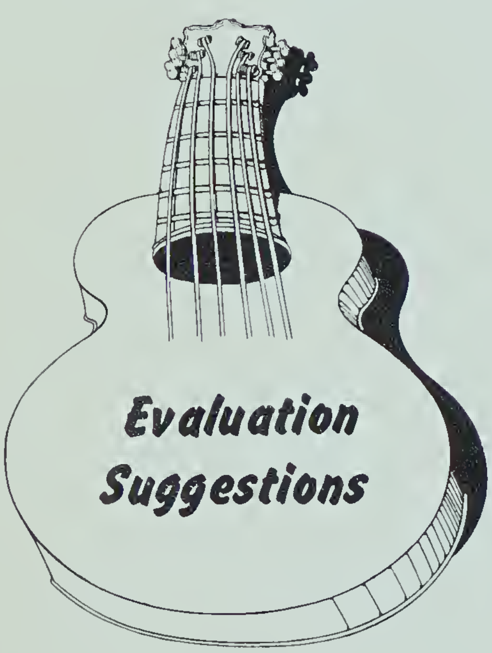
10. Disconnect the wire from the + vertical input terminal and the scope is ready for use.

For Activity 14, be sure that the scope is set for DC (direct current) operation.

Tuning Forks

The tuning forks supplied with this minicourse are middle C, at a frequency of 262 cycles per second, and middle A, at a frequency of 440 cycles per second. Middle A is used to tune the instruments of an orchestra because, by international agreement, its pitch has been set at 440 cycles per second. This pitch is sometimes called concert pitch.

Not all tuning forks for middle C and A are 262 and 440 cps, respectively. There are variations in frequency depending on the scale. For example, a set of tuning forks for the diatonic scale has middle C with a frequency of 256 cycles per second and middle A at 426.6 cycles per second.



In addition to the Minicourse Test, you might use some or all of the following suggestions to evaluate your students.

Essay Questions

Four essay questions and their possible answers follow. All are related to core material.

1. A microphone converts sound waves into electrical impulses, which are then amplified and changed back to sound waves by a speaker. Describe how the structures of the ear convert sound waves to nerve impulses.

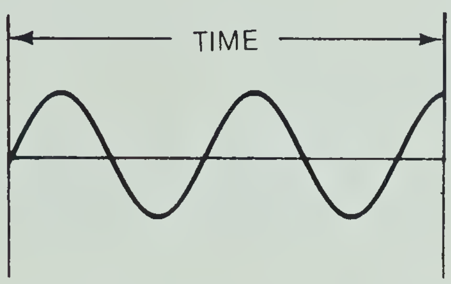
Answer: The eardrum vibrates when sound waves reach it. The vibrations of the eardrum cause the three small bones in the middle ear to vibrate, which amplifies and carries the sound vibra-

tions to the cochlea in the inner ear. The cochlea senses the different frequencies from the vibrations. Part of the cochlea, the organ of Corti, interprets these vibrations as differing frequencies and intensities and then relays this information as nerve impulses to the brain.

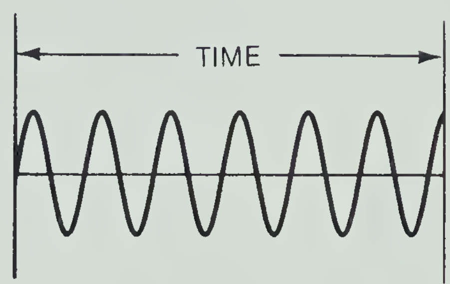
2. Describe the difference between pitch and loudness of a musical sound. Relate this difference to sound waves. Also describe the difference as it relates to a picture of the sound on an oscilloscope.

Answer: Pitch is dependent upon frequency, or the number of vibrations per second. The more vibrations per second, the higher the pitch. Two tones of different pitch might look as follows on the oscilloscope:

low pitch

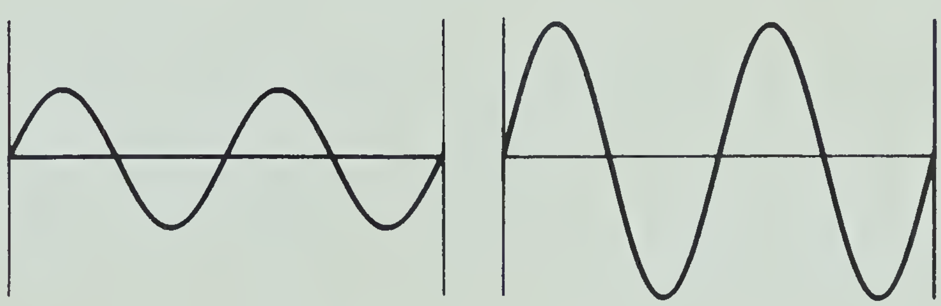


high pitch



The loudness of a specific pitch results from the strength of the vibrations. The oscilloscope indicates loudness by the height of the wave.

soft loud

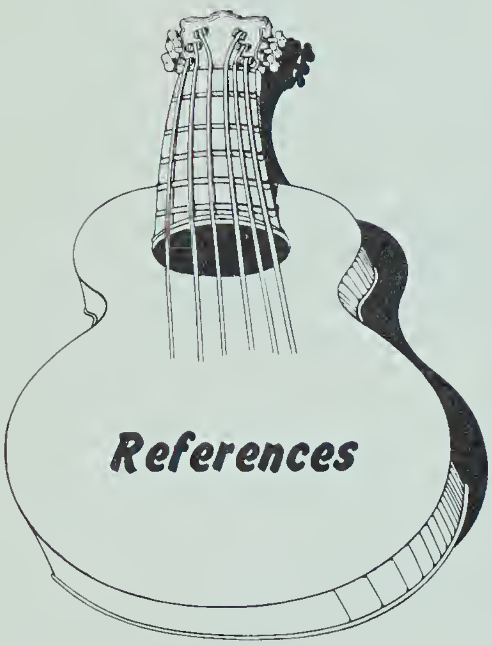


3. As a person grows older, diminished hearing is often a part of the aging process. Not only must sounds be louder to be heard, but older people often lose the ability to hear the lower (bass) and higher (treble) pitches in music. In what ways does this loss of ability to hear certain frequencies affect a person's ability to enjoy music?

Answer: Since the full range of pitches cannot be heard, the music sounds incomplete—the subtle bass and treble frequencies are lost. A person so afflicted cannot hear the complete range of frequencies; what is heard may sound like a cheap radio.

4. Describe how different notes are produced in stringed, brass, and woodwind instruments. Why wouldn't these instruments sound alike if they were played at the same pitch and loudness?

Answer: Stringed instruments change pitch when the thickness, length, or tension on a string is changed. Brass instruments vary pitch by changing the length of the vibrating air column and by controlling the air flow into the air column. The shape of a woodwind and the length of its air column affect its pitch. The instruments do not sound alike because each produces its own characteristic overtones. Overtones are secondary vibrations which result from the shape and composition of the instrument.



Benade, Arthur H. 1970. *Horns, strings and harmony.* Garden City, N.Y.: Doubleday & Company, Inc.

A very readable, small book on musical instruments and the sounds they make. Suitable for reference and background information for teachers as well as for interested students.

Stevens, S. S., and Warshofsky, Fred. 1967. *Sounds and hearing.* Life Science Library. New York: Time, Inc.

An excellent resource suitable for use by all students. The picture essays on sound waves, the ear, and musical instruments are particularly appropriate to this minicourse.

Pickering and Company, Inc. 1973. *The instruments of the orchestra.* 101 Sunnyside Blvd., Plainview, N.Y., 11803.

A well-written, highly readable booklet on the history of musical instruments. Suitable for teacher and student use. The booklet can be purchased at low cost from the publishing company or from some hi-fi retailers.

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Acknowledgments

In addition to the major effort by the ISIS permanent staff, writing conference participants, and author-consultants (listed on the inside back cover), the following contributed to this minicourse.

Art created by: Michael Eagle

Design and production supplied by: Ray Boultinghouse, Inc./Harry Rich

Photographs supplied by: Ray Boultinghouse, Inc., pp. 11, 14, 52, 53; Black Star, p. 20; Beth Bergman, p. 20; Bell Telephone Laboratories, Inc., p. 21; Polymenakos/LPL, p. 29; Pictorial Parade, p. 34; Robert Lee Cocanougher/Florida State University, pp. 42, 43, 58, 59, 62; Scott Instrument Laboratories, p. 70

Cover designed by: Martucci Studio

Special consultants: D. Graham Holmes, Assistant Professor of Mechanical Engineering, Massachusetts Institute of Technology; Raymond L. Kickliter, Choral Director, Leon High School, Leon County School District

The work presented or reported herein was supported by a grant from the National Science Foundation. However, the opinions expressed herein do not necessarily reflect the position or policy of the National Science Foundation, and no official endorsement by that agency should be inferred.

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FOREWORD

Evidence has been mounting that something is missing from secondary science teaching. More and more, students are rejecting science courses and turning to subjects that they consider to be more practical or significant. Numerous high school science teachers have concluded that what they are now teaching is appropriate for only a limited number of their students.

As their concern has mounted, many science teachers have tried to find instructional materials that encompass more appropriate content and that allow them to work individually with students who have different needs and talents. For the most part, this search has been frustrating because presently such materials are difficult, if not impossible, to find.

The Individualized Science Instructional System (ISIS) project was organized to produce an alternative for those teachers who are dissatisified with current secondary science textbooks. Consequently, the content of the ISIS materials is unconventional as is the individualized teaching method that is built into them. In contrast with many current science texts which aim to "cover science," ISIS has tried to be selective and to limit our coverage to the topics that we judge will be most useful to today's students.

Obviously the needs and problems of individual schools and students vary widely. To accommodate the differences, ISIS decided against producing tightly structured, pre-sequenced textbooks. Instead, we are generating short, self-contained modules that cover a wide range of topics. The modules can be clustered into many types of courses, and we hope that teachers and administrators will utilize this flexibility to tailor-make curricula that are responsive to local needs and conditions.

ISIS is a cooperative effort involving many individuals and agencies. More than 75 scientists and educators have helped to generate the materials, and hundreds of teachers and thousands of students have been involved in the project's nationwide testing program. All of the ISIS endeavors have been supported by generous grants from the National Science Foundation. We hope that ISIS users will conclude that these large investments of time, money, and effort have been worthwhile.

Ernest Burkman
ISIS Project
Tallahassee, Florida

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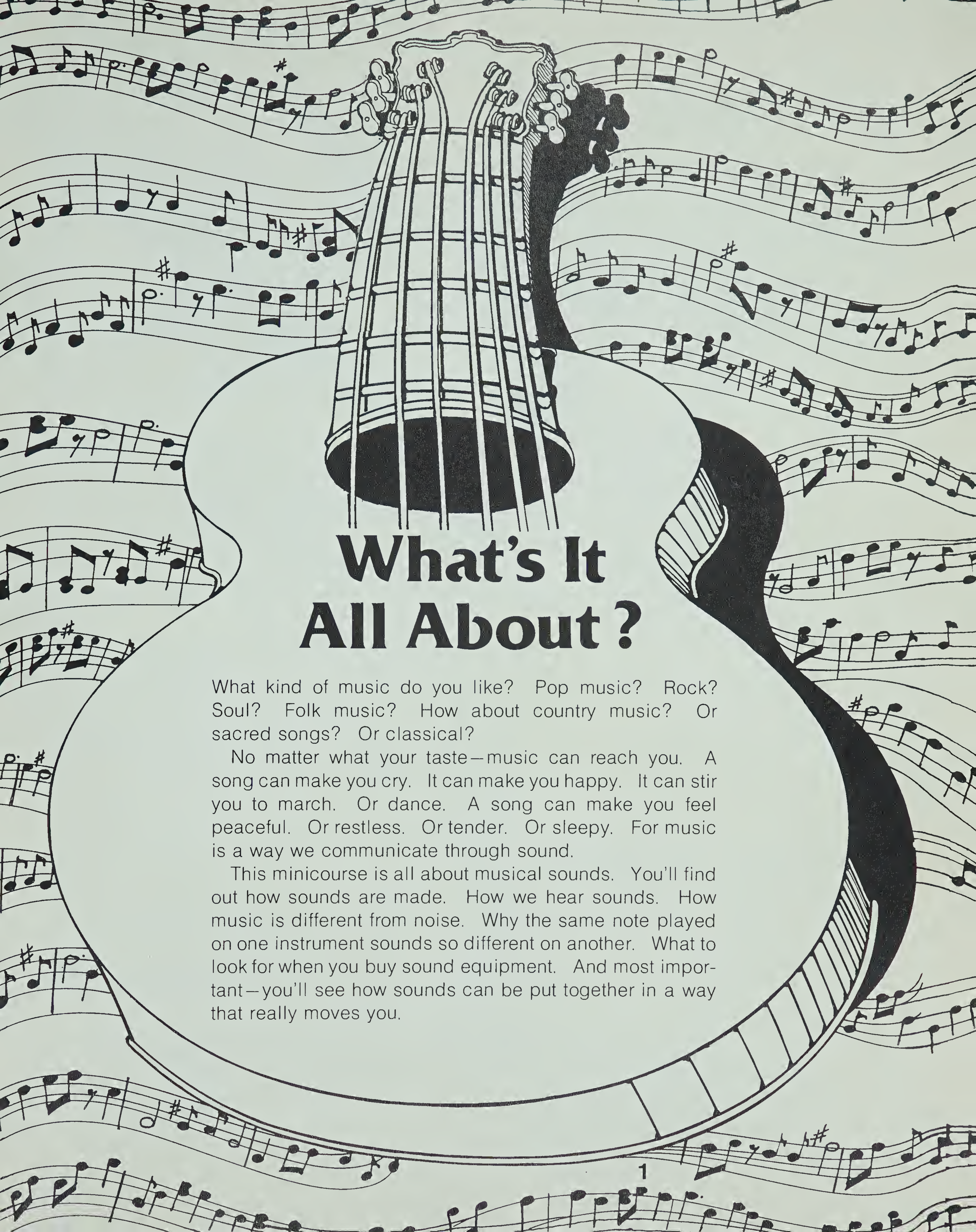
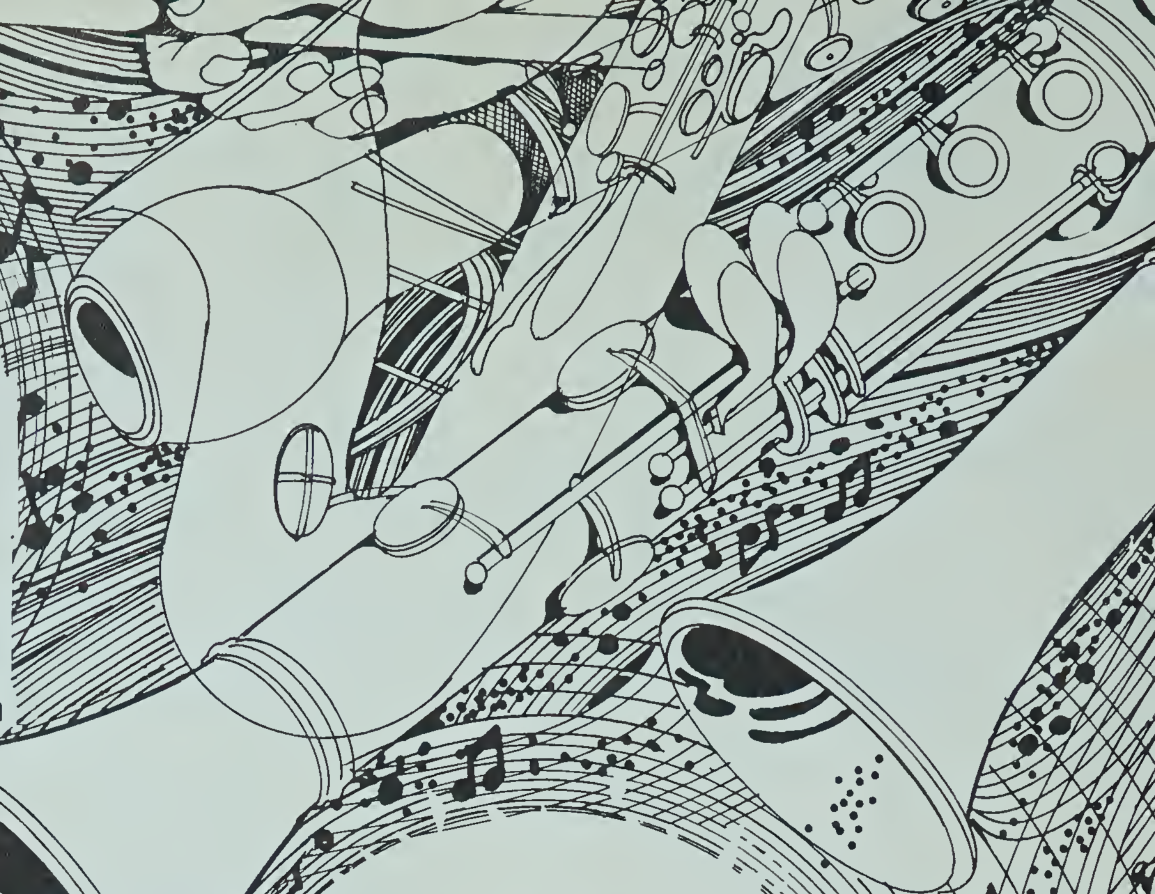


What's It All About?

What kind of music do you like? Pop music? Rock? Soul? Folk music? How about country music? Or sacred songs? Or classical?

No matter what your taste—music can reach you. A song can make you cry. It can make you happy. It can stir you to march. Or dance. A song can make you feel peaceful. Or restless. Or tender. Or sleepy. For music is a way we communicate through sound.

This minicourse is all about musical sounds. You'll find out how sounds are made. How we hear sounds. How music is different from noise. Why the same note played on one instrument sounds so different on another. What to look for when you buy sound equipment. And most important—you'll see how sounds can be put together in a way that really moves you.



core

Activity 1 Planning

If you need to do Activities 2 and 3, do them first.

If you plan to do Activity 8 or 9, make sure you can do what is stated in the objectives in Activity 7. Do the rest of the activities in any order.

Activity 2 Page 6

DO THIS FIRST

Objective 1: Explain how sound is produced and how it travels.

Sample Question: Tell whether each of these statements is True or False.

a. Sound is produced by a vibrating object.

b. Sound travels as compression bands in the air.

c. Sound can travel everywhere, even through a vacuum.

d. Sound causes air molecules to move.

Objective 2: Distinguish between observations about sound and explanations about sound.

Sample Question: Which of the following is an observation that can be made about sound?

a. Sound travels as a wave of compression bands.

b. The loudness of a sound decreases as you get farther from the source of the sound.

c. The pitch of a sound depends on the frequency of the vibrating object.

Activity 3 Page 11

DO THIS AFTER ACTIVITY 2

Objective 3: Explain how sounds can be high or low, loud or soft.

Sample Question: The loudness of a sound depends upon

a. how fast the vibration is.

b. how strong each compression is.

c. how high or low the frequency is.

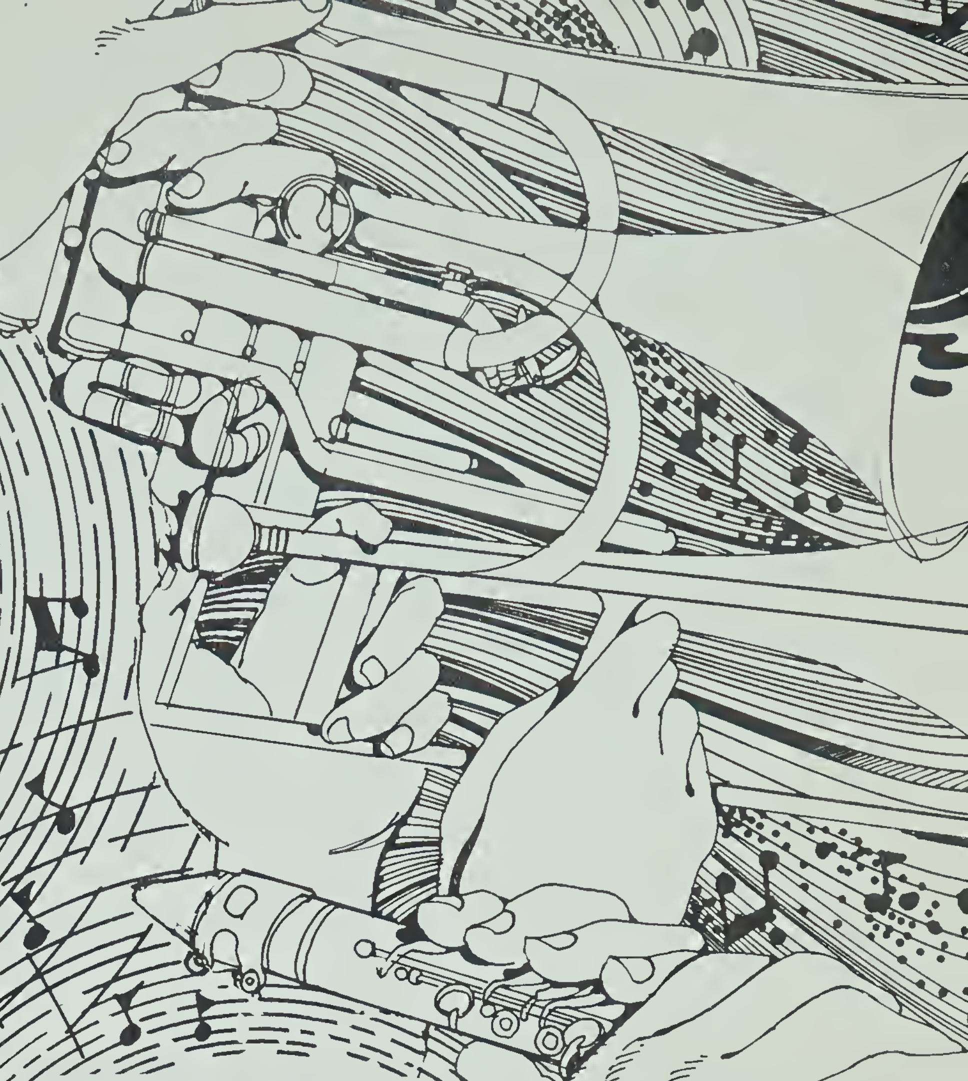
Objective 4: Explain why a sound is softer the farther away you are from the producer of the sound.

Sample Question: Why does a note sound loud when you are close to the instrument and softer when you are farther away?

a. The frequency of the note decreases as the distance from the instrument increases.

b. The number of compressions per second is reduced as the distance increases.

c. The energy of the sound reaching your ear is less the farther away you are from the instrument.



Activity 4 Page 16

Objective 5: Describe the difference between music and noise.

Sample Question: The sound waves of a noise

a. have a series of evenly spaced compressions.

b. have no regular pattern of compressions.

c. come from objects that vibrate slowly.

d. have many compressions per second.

Activity 5 Page 20

Objective 6: Tell how a singer produces different notes.

Sample Question: Match the voice sounds with how they might be produced by a singer.

Voice Sound

a. High pitch

b. Low pitch

How Produced

1. opening the sinus cavities

2. relaxing the vocal chords while singing

3. tightening the vocal chords while singing

4. singing "through the nose"

Activity 6 Page 23

Objective 7: Compare your ability to hear sounds with that of other people.

Sample Question: With normal hearing,

a. you can hear from about 20 cps to 20,000 cps.

b. your hearing range will decrease with age.

c. your hearing range may differ slightly from other people.

Objective 8: Explain how sounds are heard by humans.

Sample Question: Match the part of the ear with its description.

Ear Part

a. outer ear

b. eardrum

c. cochlea

Description

1. increases amount of vibration

2. filled with liquids and nerves

3. membrane that vibrates

4. helps funnel sounds into ear canal

Answers

1. *T, T, F, T* 2. *b* 3. *b* 4. *c* 5. *b* 6. *a-3, b-2*
7. *a, b, and c* 8. *a-4, b-3, c-2*

Activity 7 Page 29

DO THIS BEFORE ACTIVITY 8 or 9

Objective 9: Describe how the air column of wind instruments must change in order to produce different pitched sounds.

Sample Question: How would you change the air column length of a trombone in order to change from a low note to a high note?

Activity 8 Page 34

DO ACTIVITY 7 FIRST!

Objective 10: Describe how the air column of reed instruments must change in order to produce different pitched sounds.

Sample Question: How does opening more holes on a clarinet produce higher notes?

a. The vibrating air column is shortened.
b. The vibrating air column is lengthened.
c. The length of the vibrating air column is unchanged.
d. The number of vibrations per second is reduced.

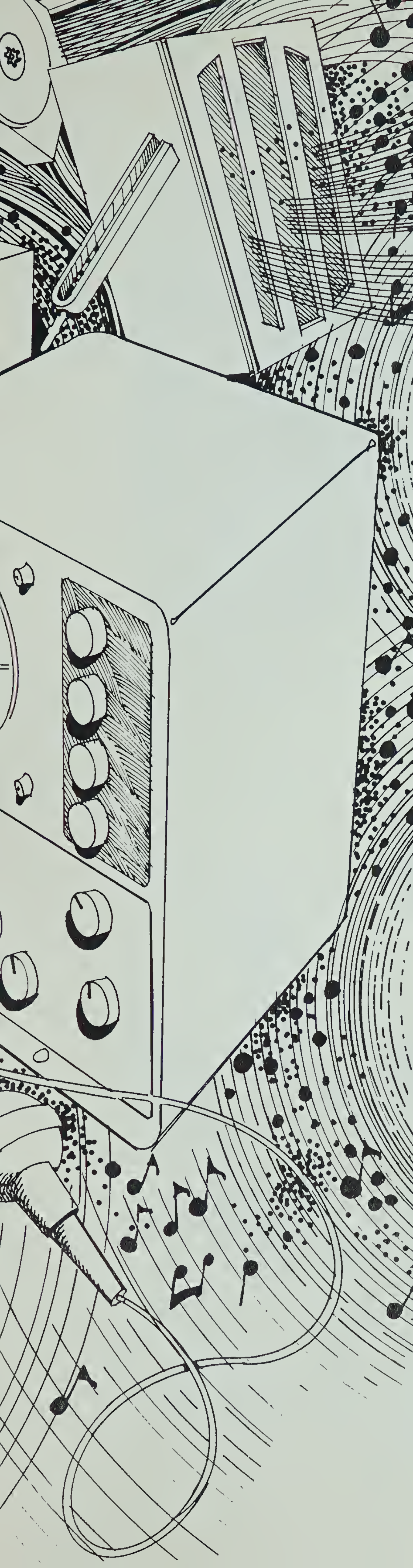
Activity 9 Page 38

DO ACTIVITY 7 FIRST!

Objective 11: Describe how stringed instruments produce sounds of different pitch.

Sample Question: On a stringed instrument the string that produces the highest note is different from the string that produces the lowest note. High strings are

a. shorter, thicker, or tighter.
b. longer, thinner, or looser.
c. longer, thicker, or looser.
d. shorter, thinner, or tighter.



Activity 10 Page 42

Objective 12: Tell why the same note sounds differently when played on different instruments.

Sample Question: A guitar note sounds different from the same note on a piano because

a. the piano is louder than the guitar.
b. the two notes have different overtones.
c. the piano can play more notes at the same time.
d. the guitar and piano are tuned differently.

Activity 11 Page 45

Objective 13: Tell how to select good quality sound equipment.

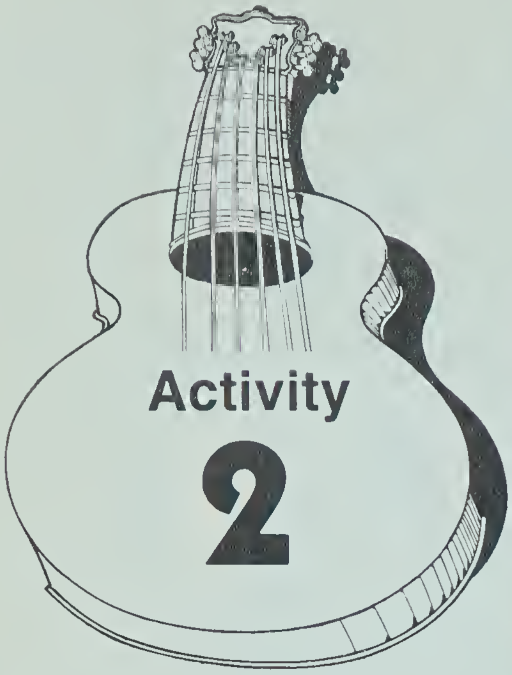
Sample Question: The best advice in selecting sound equipment is the following:

a. You should be satisfied with the sound.
b. You should follow the advice of those consumer magazines which rate sound equipment.
c. You should get the most expensive equipment you can afford.
d. You should buy a good set of speakers.

Answers

9. *Shorten the air column length.* 10. *a*
11. *d* 12. *b* 13. *a, b*

ACTIVITY EMPHASIS: Using a tuning fork, students investigate how a sound wave is produced and how it travels.



Activity 2

Good Vibrations

MATERIALS PER STUDENT UNIT
tuning fork
rubber striker
beaker, 250-ml, or jar

Everyone makes sounds. Some are musical. Some are not. Yet all sounds have the same beginning. To find out what sound is, you will need these items:

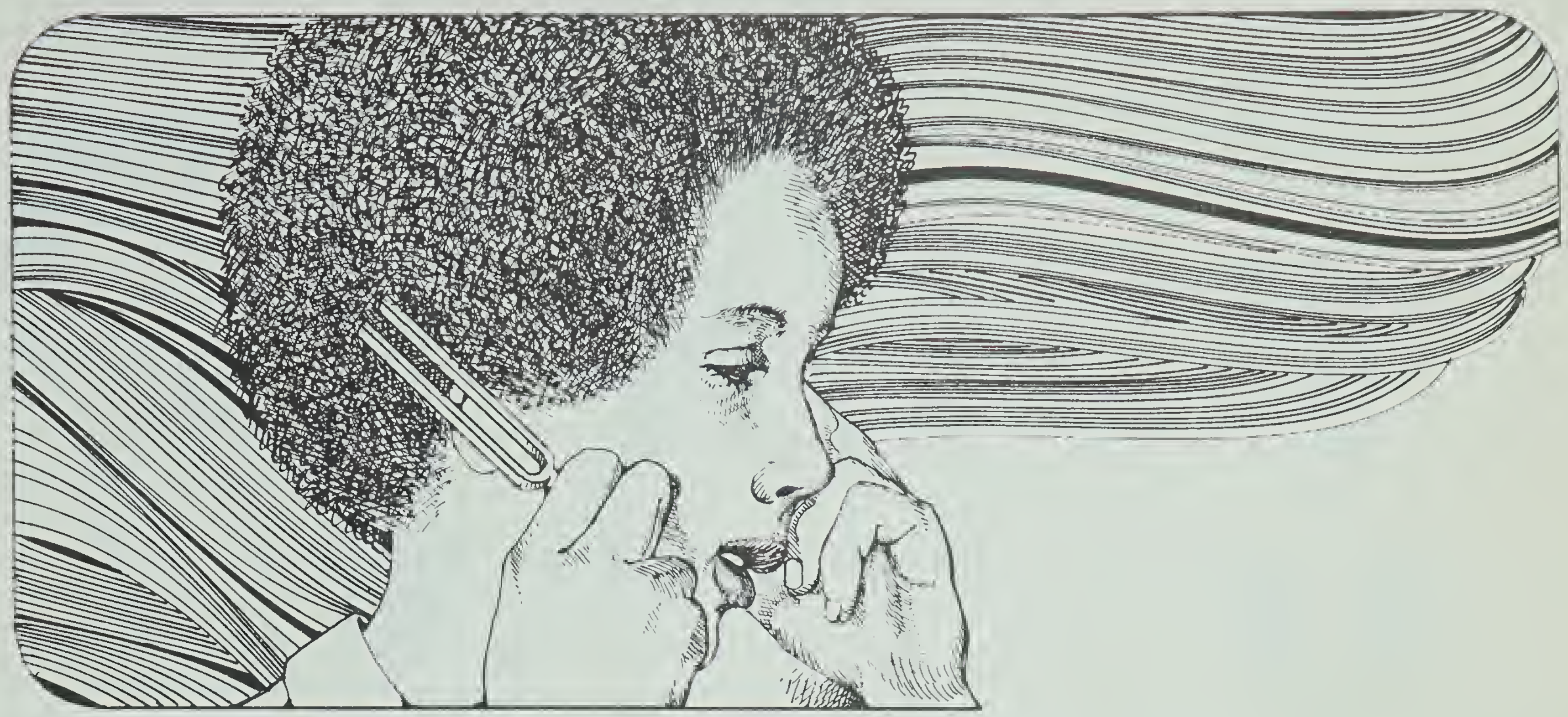
tuning fork
rubber striker
beaker or jar

IMPORTANT: Never hit the tuning fork against objects. Always use the rubber striker.

A. Strike the tuning fork with the rubber striker.

✔ 2–1. Do you hear a sound? If so, where does it seem to come from? Do Step B to check if the sound comes from the tuning fork. 2-1. Yes, if you hold the tuning fork close to your ear. From the prongs of the tuning fork.

B. Hit the prongs of the tuning fork with the striker. Then put the handle against your jawbone. Close the ear on the opposite side of your head.

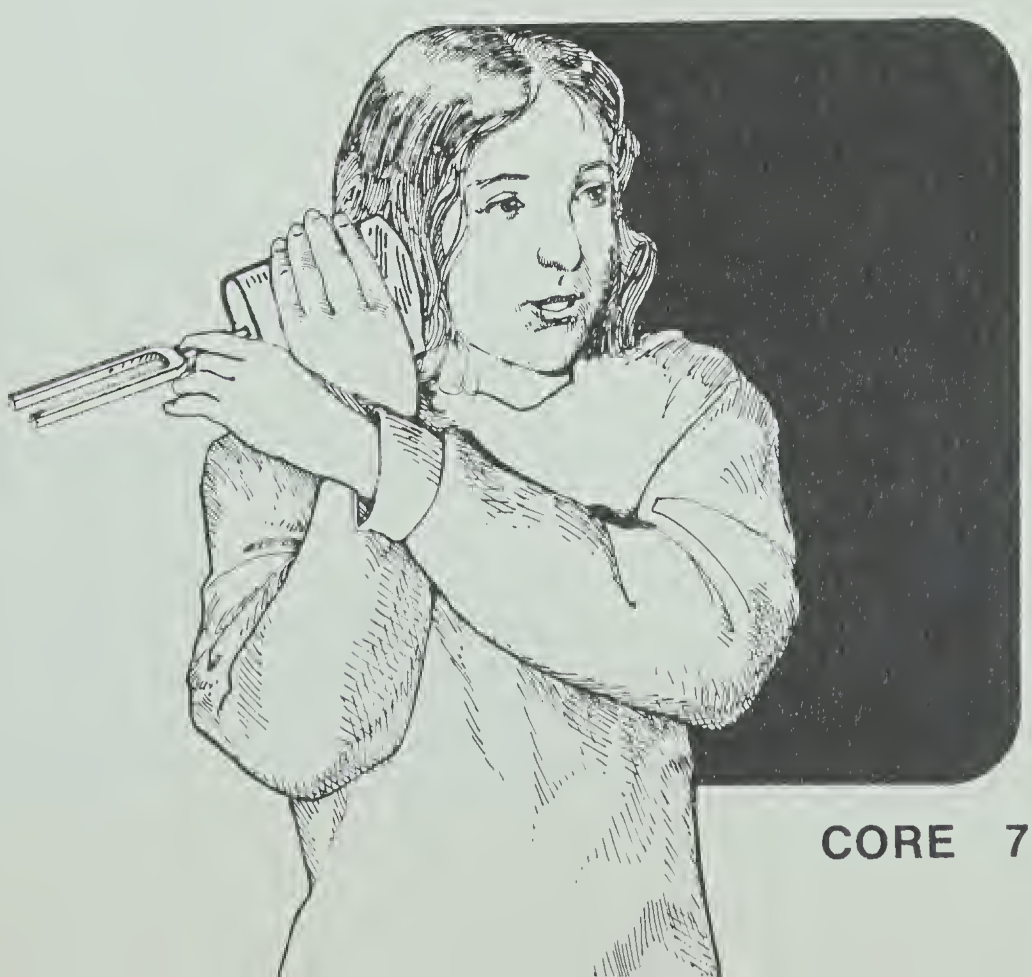


2-2. Students should report a loud humming sound. A tingling sensation is felt.

2–2. What do you hear? What do you feel against your jawbone?

You have observed that the tuning fork produces a sound when you strike the prongs. You can make that sound louder.

C. Place the open end of the beaker or jar tightly over one ear. Hit a prong of the tuning fork with the striker. Immediately touch the handle to the bottom of the beaker.

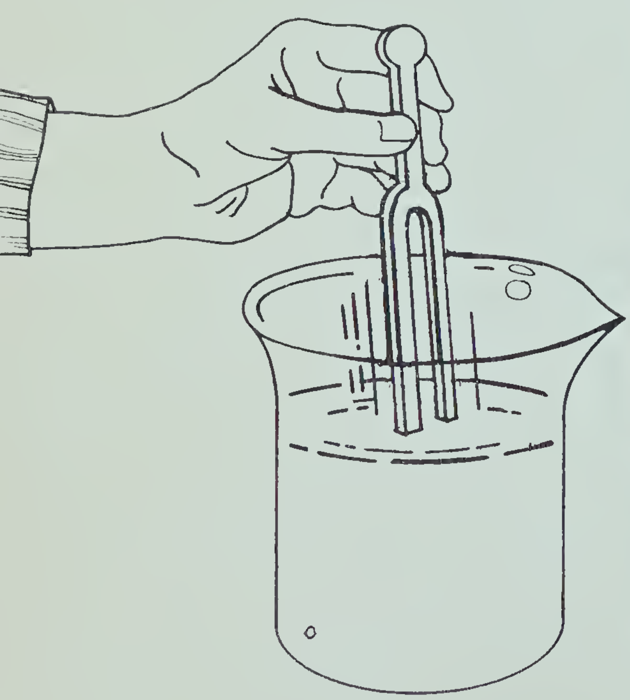


2–3. What other ways can you find to make the sound louder? 2-3. By striking the tuning fork harder; by placing tuning fork on a large surface, such as a window pane or desk.

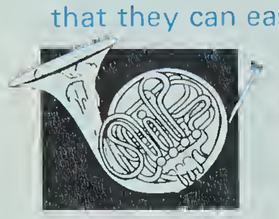
D. Hit the tuning fork with the striker again. Look at the prongs.

2–4. How do the prongs look? 2-4. They appear to be blurry.

When you strike the tuning fork, the prongs move back and forth very fast. These movements are called *vibrations*. The vibrations are hard to see because the prongs are moving so rapidly for such a short distance. Probably all you can see are the ends of the prongs looking fuzzy. To check that the prongs do vibrate, do Step E.



E. Fill the beaker or jar about 3/4 full with water. Strike the tuning fork as before. Then touch just the tips of the prongs to the water's surface. Caution students not to fill the beakers more than ¾ full of water. If the beakers are overfilled, students will discover that they can easily splash water over large distances.

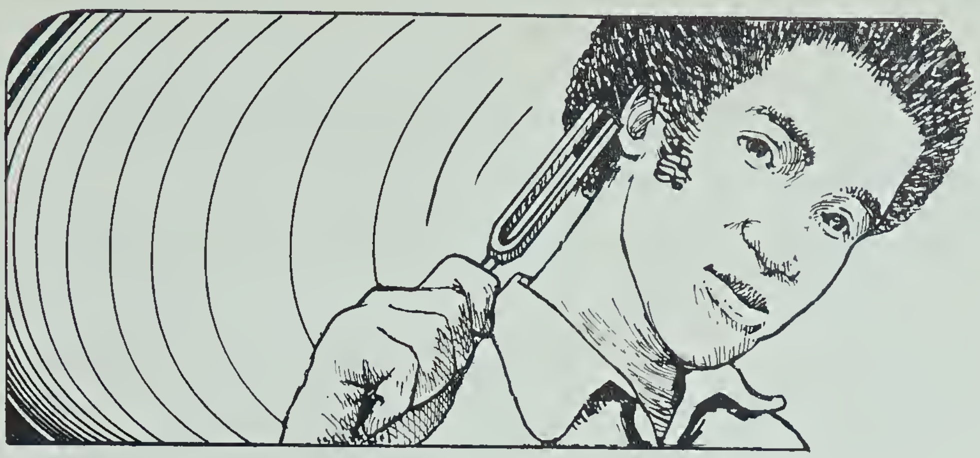


IMPORTANT: Do not touch the glass walls with the fork!

2–5. What happens to the water? 2-5. The water splashes as it comes into contact with the tuning fork.

2–6. How does this show that the prongs are moving? 2-6. The splash must be a result of the vibrating prongs.

F. Strike the tuning fork one more time. Very lightly, touch the tip of one prong to the tip of your earlobe.



✔ 2–7. Describe the feeling when you touched the fork to your earlobe. 2-7. You should feel a tickling sensation.

So far you've been making some *observations* about sound. Observations are what you know from your senses—seeing, hearing, touching, smelling, tasting. The observations you've made are interesting. But people are always asking "Why?" Why does a note sound loud or soft? Why do you hear a sound over here if it was made over there?

Scientists try to figure out explanations to these kinds of questions. And people seem to like the simplest explanations the best. So, the explanation for sound uses the same idea of molecules that is used to explain many other observations about our world. 2-8. Check that student answers are actually *observations* and not inferences based on observations.

✔ 2–8. What observations have you made about sound so far?

✔ 2–9. Does it seem reasonable that the vibrations you felt may have caused the sound you heard? Explain your answer. 2-9. Yes. The vibrations and the sound were observed to always occur together.

Sound begins when something vibrates. That "something" can be a tuning fork, a violin, a drum, a glass, or any object. The vibrations move through the air until they reach your ears, where you hear them as sound.

Suppose you could see the sound moving from the tuning fork to your ear. What would the sound look like? First of all, sound must have something to travel through. It can't travel through a vacuum. But it can travel through air, water, or metal. In fact, it can travel through any solid, liquid, or gas.

When you strike the tuning fork, the prongs move back and forth. Figure 2–1 shows what happens during one vibration of the fork. As the prong moves outward, it pushes against air molecules nearby. When the prong moves inward, the air molecules spread out.

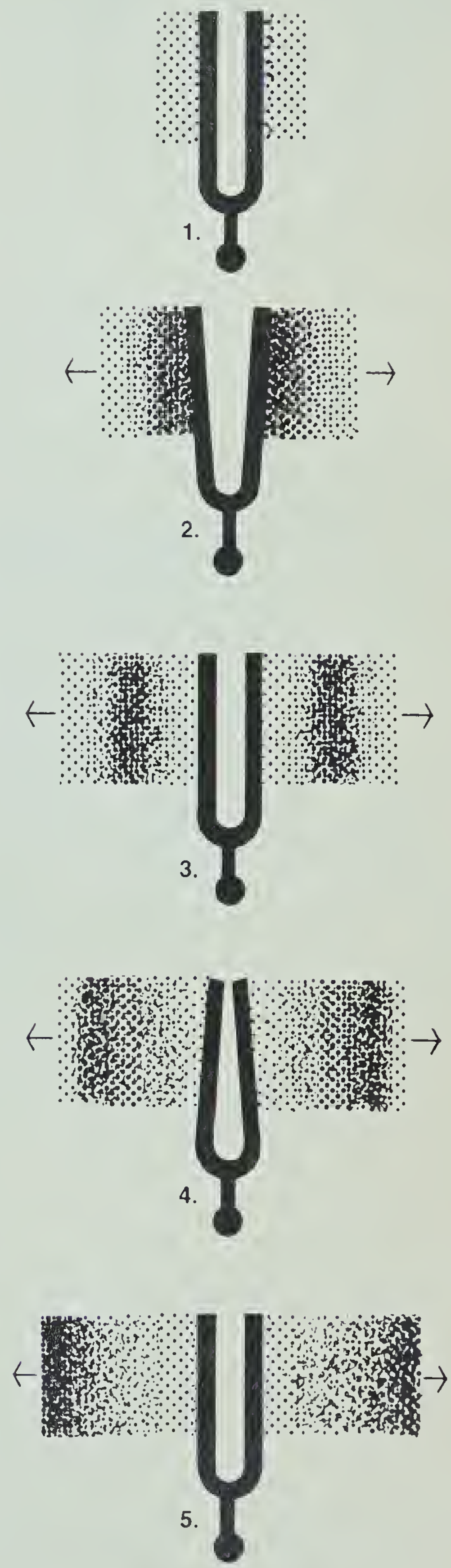


Figure 2–1

As the prongs of the tuning fork move one way, the air particles are compressed, causing higher air pressure. When the prongs move in the other direction, the air particles spread apart, causing lower air pressure.

A sound wave is an example of longitudinal wave motion. The particles of the medium vibrate in the same direction as the energy travels.

But how does the sound get over to your ear if only the air next to the prong squeezes together and spreads apart?

What happens is that the prongs set up a "disturbance" in the air. Remember what happened when you dipped the tuning fork into the water? The vibrations set up little waves that you could see. Something like that happens in the air. The molecules that are pushed push against other molecules. They in turn push against still others. In this way, each molecule doesn't travel very far. But the disturbance does. This disturbance is similar to what happens when you throw a pebble into a pond.

When the air molecules are squeezed together, the air is said to be *compressed*. When the molecules spread apart, the air is *rarefied*, or thinned out. When a tuning fork—or anything else—vibrates, equally spaced bands of compressions and rarefactions move through the air all around the fork. These are called *sound waves*. There may be a single compression or a set of compressions, one following another.

✔ 2–10. Does the tuning fork set up a single sound wave or a series of sound waves? 2-10. A series of sound waves.

Figure 2–2 shows how a sound wave travels from the tuning fork to a person's ear.

★ **2–11. How is sound produced?**

2-11. Sound is produced by a vibrating object.

★ **2–12. How does sound travel through air?**

2-12. In the form of sound waves, which are a series of compressions and rarefactions of air molecules.

Figure 2–2

ACTIVITY EMPHASIS: What is meant by the frequency of a sound wave; how frequency affects pitch; how to produce louder sounds.

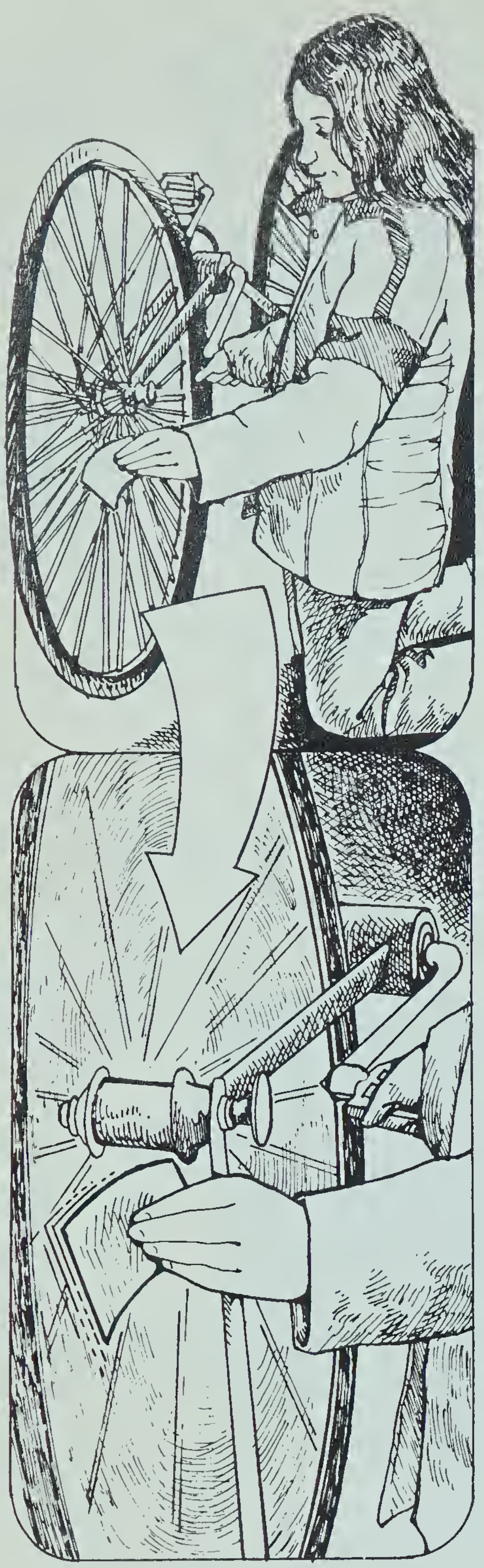
Sounds and Cycles

Sounds come at us from all directions. We hear low sounds and high sounds. Loud sounds and soft sounds. Pleasant sounds and harsh sounds. What makes each sound so different? To find out, you'll need these items:

bicycle (If not available, use a comb to do this activity.)
stiff card

MATERIALS PER STUDENT UNIT
bicycle or comb
stiff card
tuning fork
rubber striker

See Advance Preparation, page TM 5.



CAUTION

Watch out for your fingers!

Turn the bicycle upside down. Hold the card against the spokes of the back wheel. First turn the wheel slowly. Listen to the sound as the spokes hit the card. Then turn the wheel faster. Observe what happens now.

✓ 3–1. As you turn the wheel faster, does the card vibrate faster or slower? Does the sound you hear become higher pitched or lower pitched? 3-1. Faster. The sound becomes higher.

Each time the spoke hits the card, the card moves back and forth, or vibrates. As the card vibrates, it makes the air around it compress and expand. Figure 3–1 shows what happens when the card vibrates for one second. The faster the card vibrates, the more compressions it forms each second. The more compressions, the higher the sound you hear.

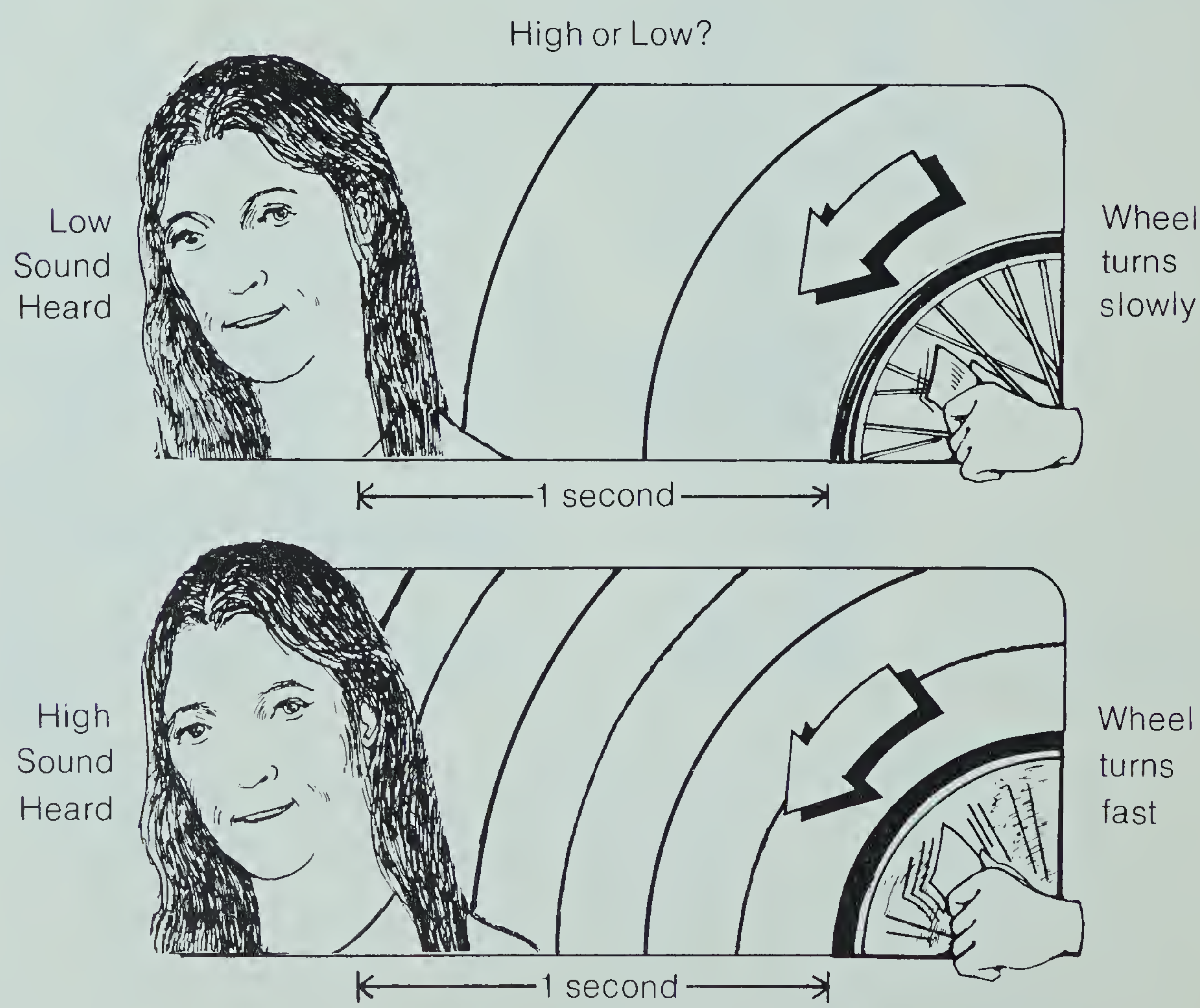
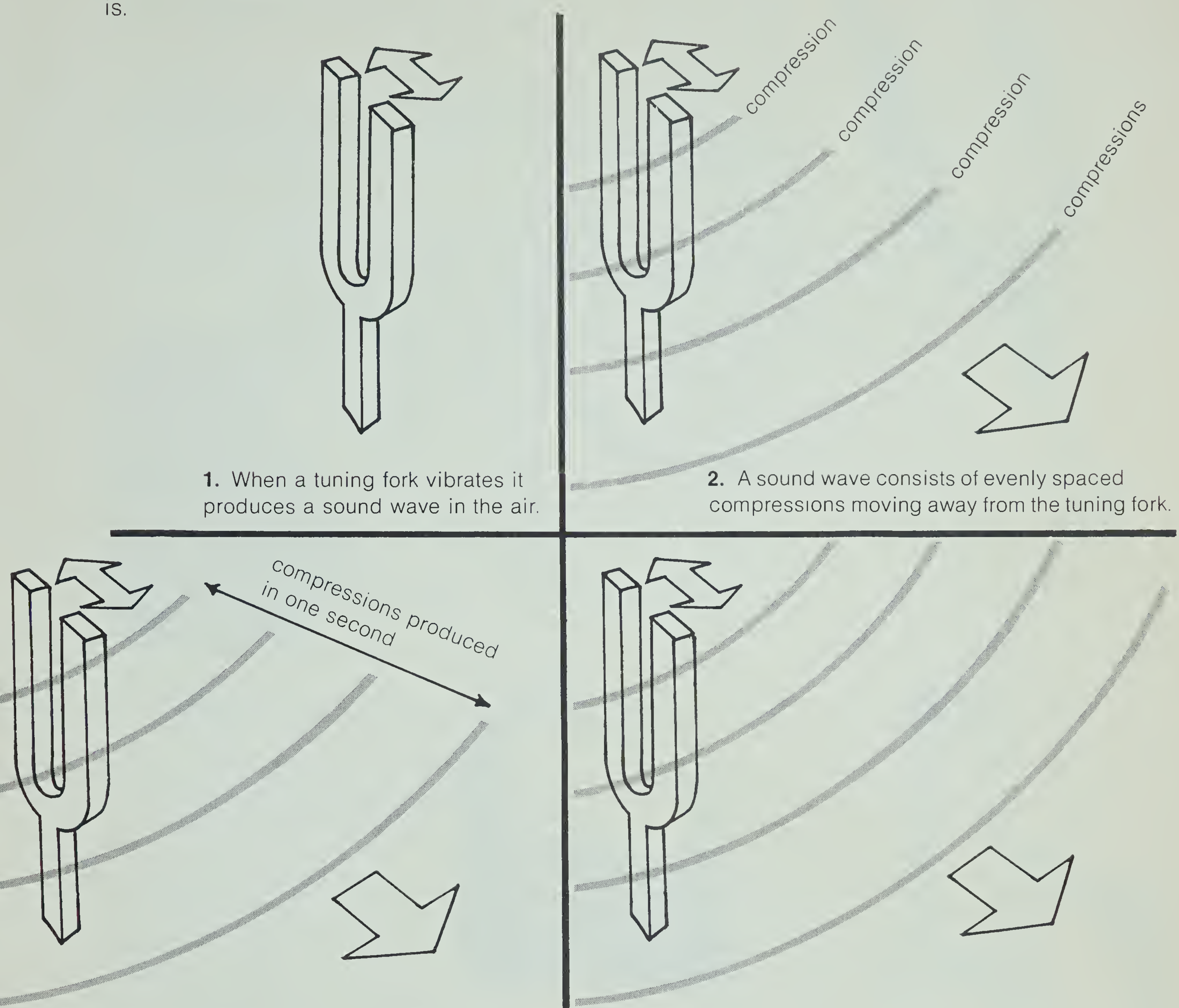


Figure 3–1

There is a way to describe just how high or low pitched a sound is.



1. When a tuning fork vibrates it produces a sound wave in the air.

2. A sound wave consists of evenly spaced compressions moving away from the tuning fork.

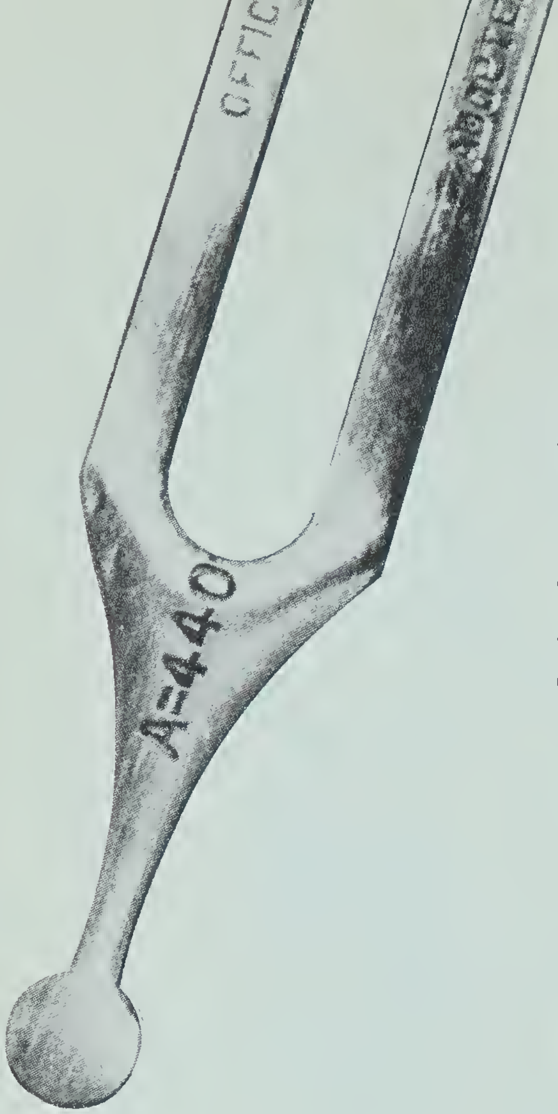
3. The number of compressions made by the fork in one second is the frequency.

4. The fork prong continues to push the air in front of it, forming other compressions.

A frequency of 50 cycles per second may also be expressed as 50 hertz (50 Hz). One hertz is equal to one cycle per second. The unit is named in honor of the German physicist Heinrich Hertz (1857-1894).

If the tuning fork shown above makes 50 vibrations each second, it produces a sound wave with 50 compressions per second. You can state this another way too: The *frequency* of the sound wave is 50 cycles per second.

✔ 3–2. What word describes the number of vibrations per second of a certain sound? 3-2. Frequency.



A tuning fork makes a sound of one frequency only. The frequency number is stamped on it. Examine two tuning forks that make different sounds. Locate the frequency for each tuning fork.

★ **3–3. How are the frequencies of high and low-pitched tuning forks different?** 3-3. The high-pitched tuning fork has a higher frequency.

You know that two sounds can be different because of their frequencies. The higher the frequency, the higher pitched the sound. Suppose you have two sounds with the same frequency. Can those sounds still be different?

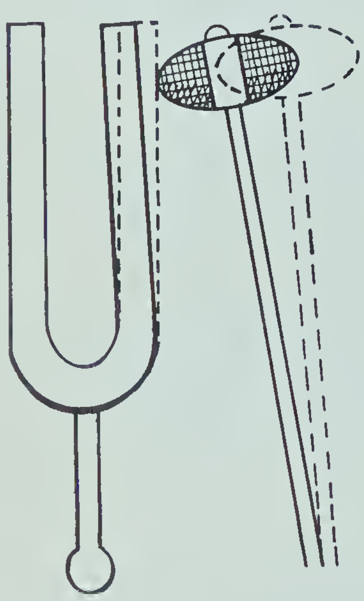
Try this way of producing a louder sound. You will need the following items:

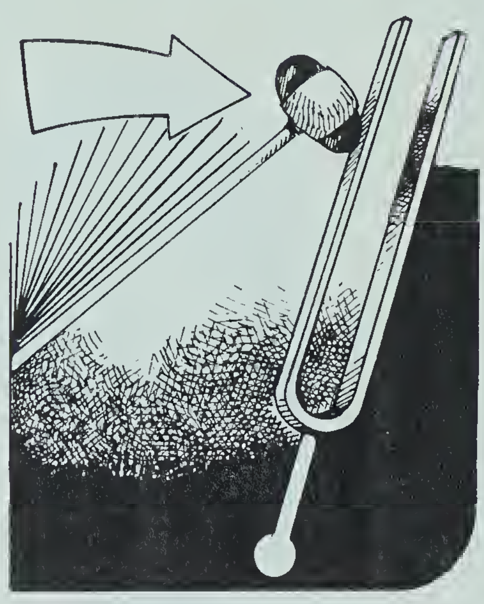
tuning fork
rubber striker

A. Tap the tuning fork gently with the rubber striker. Listen to the sound.

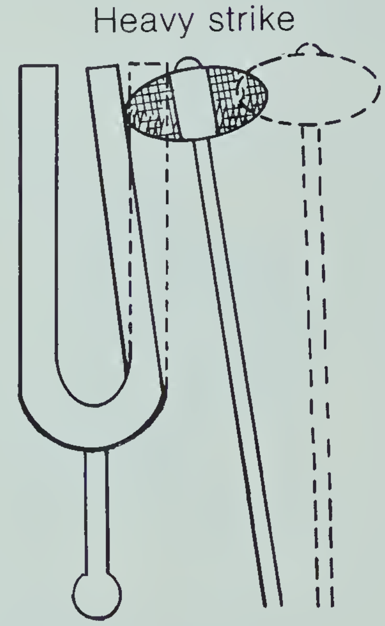
B. Now strike the tuning fork harder than in Step A.

Light strike





Heavy strike



✔ 3–4. Which sound was louder—the one you made in Step A or Step B? 3-4. Step B.

By striking the tuning fork harder, you made its vibrations larger but not faster. The prongs now move farther apart than when the tuning fork is hit lightly. This produces stronger compressions and a louder sound. Stronger compressions have more energy.

The loudness of a sound depends on how much energy the sound wave has when it gets to your ear.

Here's another way to produce a louder sound. You will still need the tuning fork and rubber striker.

C. Strike the tuning fork with the rubber striker. Then hold the fork near your ear. Count how long you can hear the sound. (Count seconds by saying, "One thousand, two thousand, three thousand," slowly.)

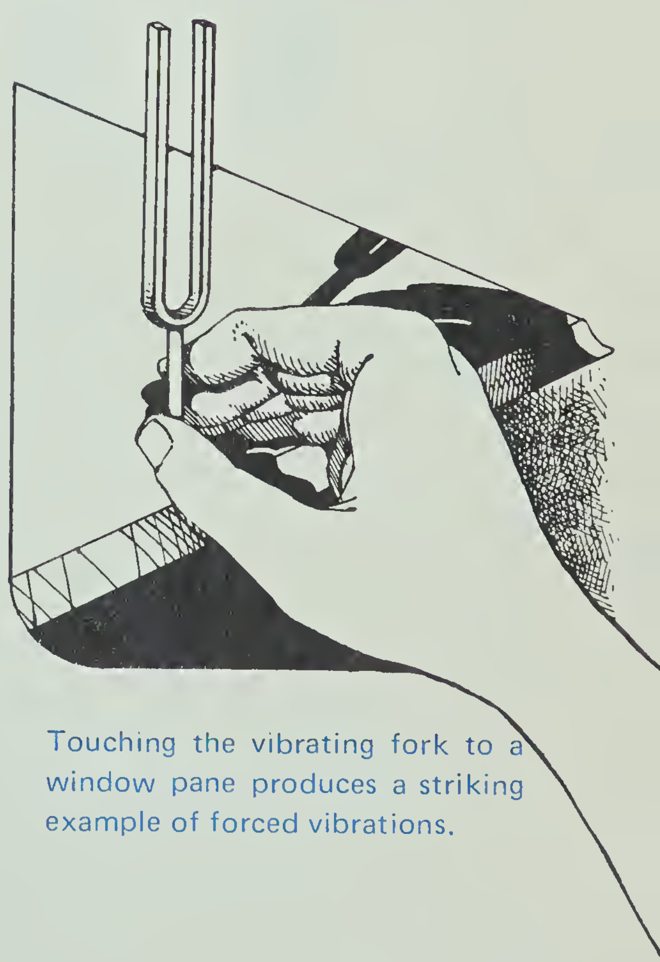
3–5. How long did you hear the sound? 3-5. Answers will vary.

D. Strike the fork with the striker again. This time hold the handle tightly to the top of a desk. Put your ear near the desk. Count how long you can hear the sound.

3–6. How long did you hear the sound? 3-6. Answers will vary, but time should be shorter than that in Question 3-5.

3–7. Which sound was louder—the one in Step C or Step D? 3-7. Step D.

3–8. Which sound lasted longer? 3-8. Step C.



Touching the vibrating fork to a window pane produces a striking example of forced vibrations.

When you put the tuning fork on the desk you were showing an example of "forced vibration." The vibrations of the tuning fork started the desk top vibrating too—at the same frequency as the tuning fork. So the area that was vibrating increased.

Since the area of vibration became larger, energy was transferred more quickly from the vibrating objects to the air. This caused stronger compressions—and therefore a louder sound. But the sound died more quickly because the energy from the vibrating fork was used up more quickly.

3-9. When the strings are plucked, they vibrate and transfer their vibration to the wooden box of the guitar. This increases the area of vibration and a louder sound is produced.

3–9. A guitar works on the basis of forced vibrations. Can you explain this?

You know that the farther you get away from something that's making a sound the less loud the sound is. That goes for bells, car motors, singers, sirens, and all other sound makers. Why is this so?

A sound wave is something like a ripple on a pond after a rock is tossed in. The wave moves out in a circle that gets bigger and bigger. But as the circle gets bigger, the wave also gets flatter and less noticeable. The energy sent out in the wave is still there. But it is spread more thinly as the circle increases. If you are close to the source, more energy hits your ear. If you are far from the source, much less energy hits your ear.

★ **3–10. Why does the loudness of a sound decrease with distance?** 3-10. The energy of the sound wave is spread out over a larger distance.

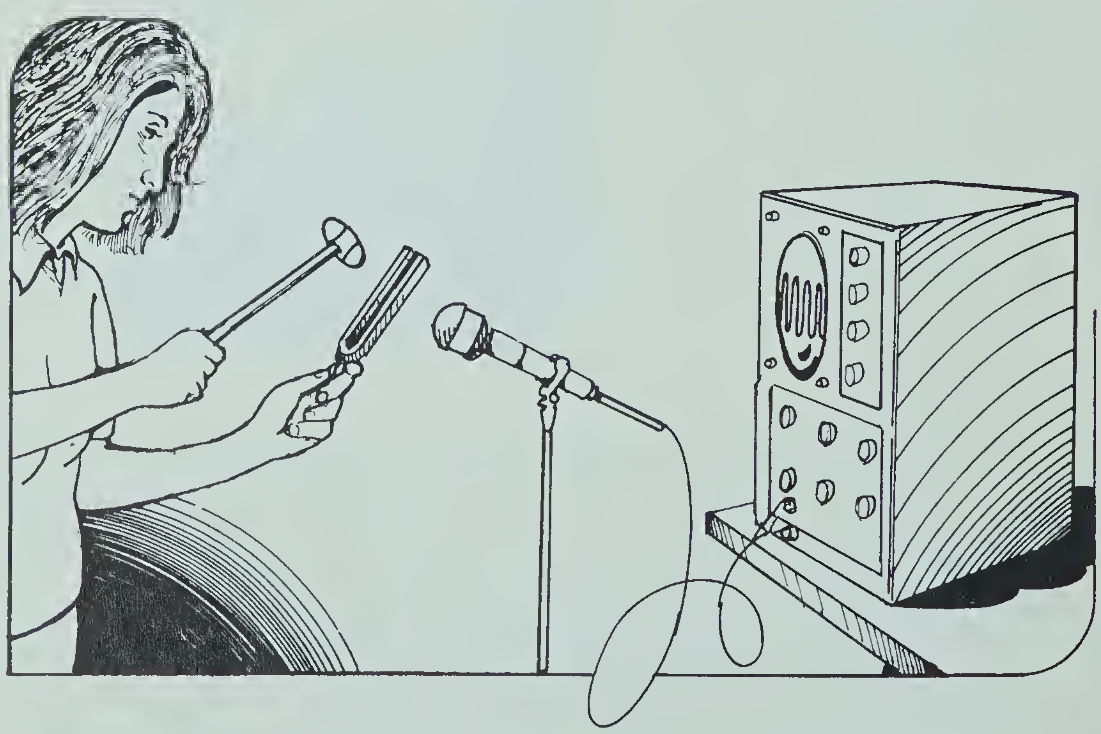
ACTIVITY EMPHASIS: Students investigate how percussion instruments produce sound and how they are used in a band or orchestra.

MATERIALS PER STUDENT UNIT
2 rubber bands

Notes or Noise?

When you strike a piano key, you hear a musical note. But when you clap your hands, you just hear a noise. What's the difference in the sounds? Or is there a difference?

Figure 4–1 shows pictures of the pattern made by the sound of a tuning fork, a person singing one note, and a hand clap.



You can "see" what sound waves are like on an oscilloscope.
The sound is fed in by the microphone.
The picture is seen on the screen.

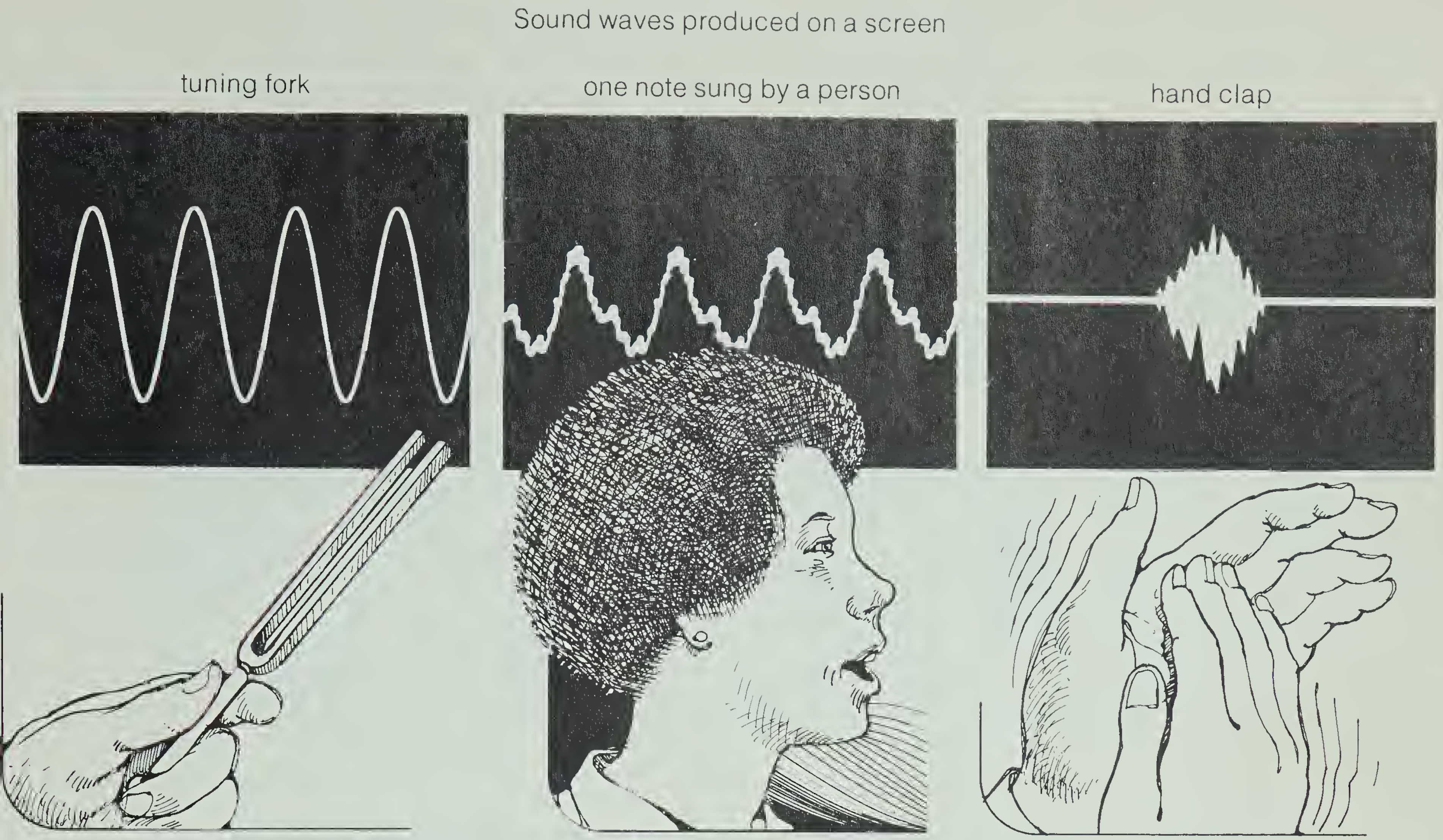


Figure 4–1

★ **4–1. How are the patterns made by the tuning fork and the human voice alike?** 4-1. They both have a pattern of peaks and valleys repeated regularly.

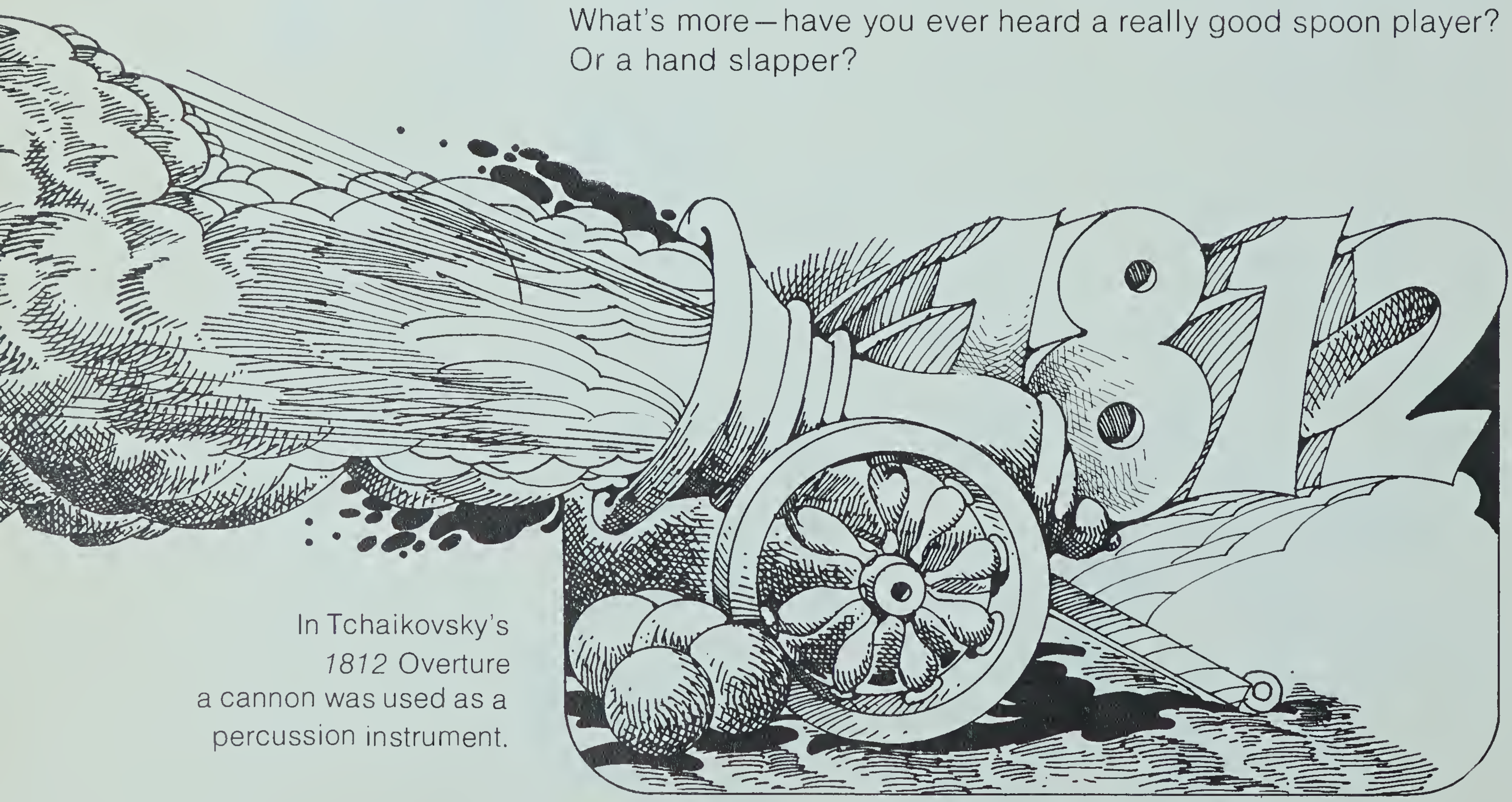
★ **4–2. How is the hand-clap pattern different from the other two patterns?** 4-2. There is no regularly repeated pattern.

You've "seen" the difference between musical and not-so-musical sounds. Sound waves of musical notes have regular patterns of compressions. This goes for sound waves from a tuning fork, a piano, or the human voice. Sound waves of noise—like a hand clap or a glass breaking—have no regular pattern of compressions.

Is all noise bad? What about the thunder of a kettledrum? Or the crash of a cymbal? Or the boom of a bongo drum? These instruments are part of a large group called *percussions*.

Figure 4–2

Figure 4–2 shows some commonly used percussion instruments. But these are not all. In fact, almost anything goes. Crashing glassware, cannon fire, and whips cracking have been used as percussion "instruments" in certain musical compositions. What's more—have you ever heard a really good spoon player? Or a hand slapper?

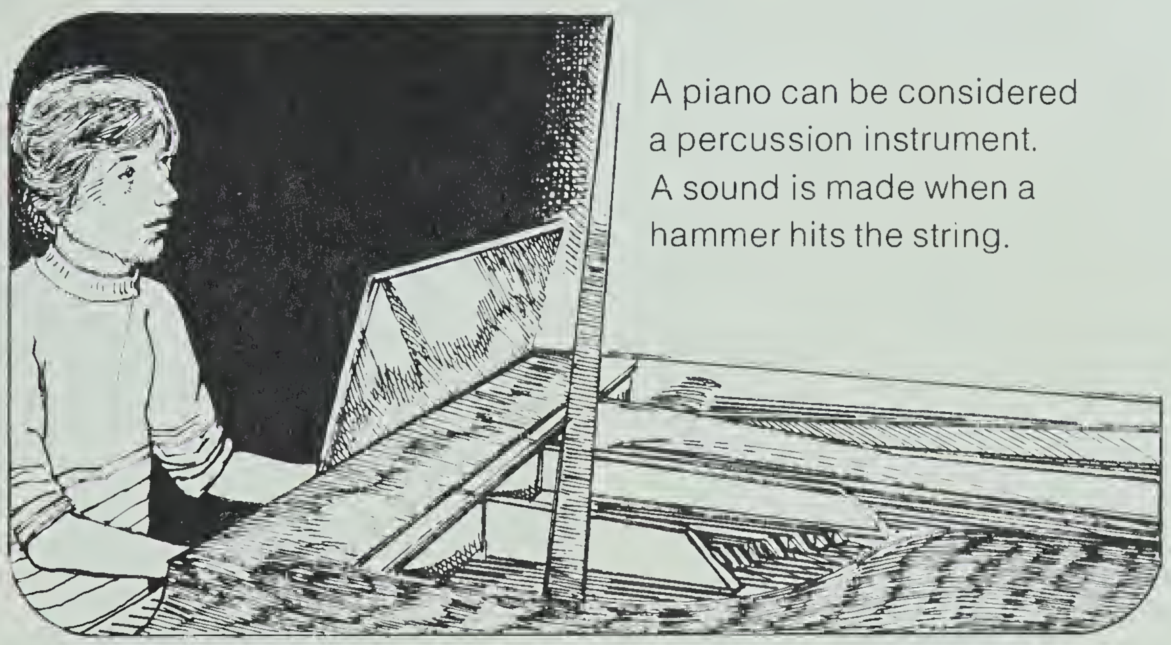


In Tchaikovsky's *1812* Overture a cannon was used as a percussion instrument.

You've probably observed the difference between the sound of a drum and that made by any other type of musical instrument. For instance, a bass drum and a tuba both make very low sounds. The tuba, however, plays musical notes. The drum makes a sound that combines a rumble with an explosion. It produces too great a mixture of sound to identify one note.

The drum that is commonly used in a West Indian steel band uses different parts of the drum head to produce different notes.

In the percussion family, the kettledrum is the only instrument that can slide smoothly from note to note. The musician presses on the foot pedal to change the notes. You can recognize each note. But the quality is still that of a drum.



A piano can be considered a percussion instrument. A sound is made when a hammer hits the string.

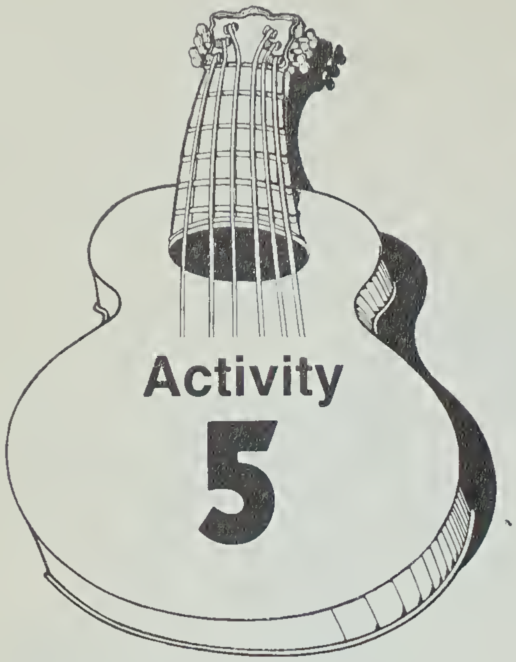
Why would anyone want to add non-musical instruments to a band or an orchestra? Percussion instruments—especially drums—are used to keep the beat in music. They are loud and can be heard above other instruments.

Drums are really important in marching bands. In fact, often only the drummers are playing when everyone else is silent.

But percussion instruments are not the only instruments used to keep the beat or rhythm. Folk singers and rock bands often use guitar strumming to keep the beat.

And the beat goes on. . . .

Pressing on the pedal tightens the head of the drum. The tighter the head, the higher the sound produced.



ACTIVITY EMPHASIS: How the human voice can produce a wide range of notes; the range of frequencies in humans versus animals and instruments.

Singing Sounds

MATERIALS PER STUDENT UNIT
cassette tape for *Sounds of Music*
cassette tape player, preferably with earphones

Many people think that the human voice is the best musical instrument of all. Like many instruments, the voice can produce a wide range of musical sounds. It can make these sounds as soft as a murmur or so loud they can be heard at the back of a large auditorium. But what makes the voice so special are the qualities a singer can give to a sound. A singer can make the same sound clear and sweet. Or harsh and raspy. Or soft and soothing. Or sultry and sexy. This variety gives singing an added excitement.

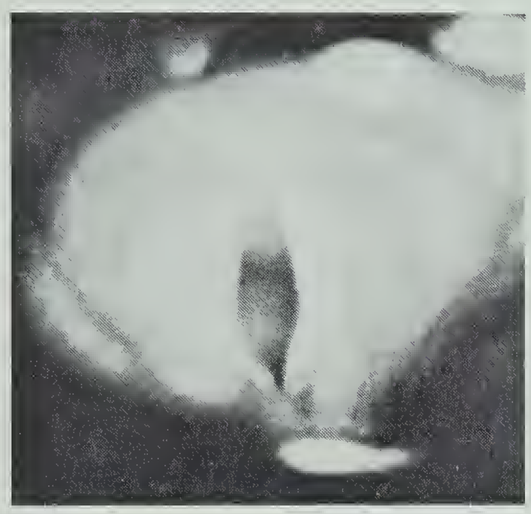
Most people sing mainly for fun, whether alone or in groups. But some make their careers entertaining the rest of us with the sounds of their voices!

In this activity you will learn about the human voice. You will need these items:

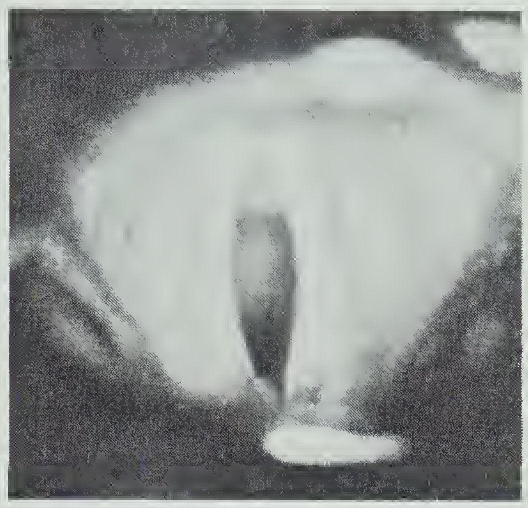
cassette tape for *Sounds of Music, Activity 5*
casette tape player

A. As you listen to the tape, look at Figure 5–1. The tape will help you answer the questions.

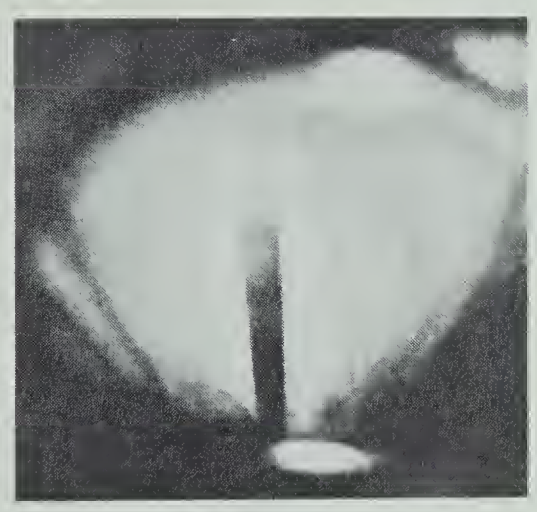
Human Larynx Producing Notes



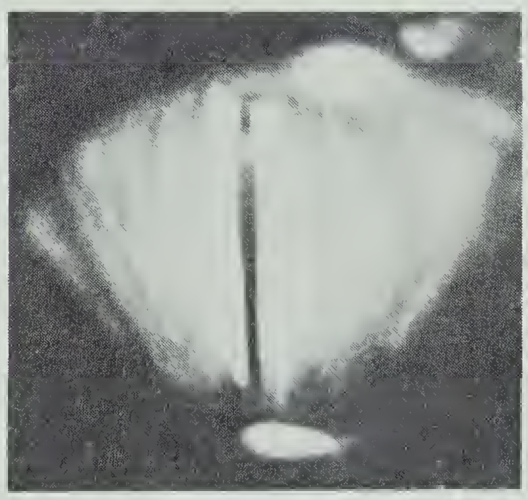
A. Low note



B. Medium note



C. High note



D. Very high note

Figure 5–1

★ **5–1. How do you produce different sounds (notes) when you talk or sing?** 5-1. You change the length and tightness of the vocal cords.

★ **5–2. How does a heavy cold affect the sound of your speaking voice?** 5-2. A cold coats the vocal cords with mucus and makes them thicker. This causes the sound produced to be lower.

✔ 5–3. Look at Figure 5–1. In which photo is the sound with the highest pitch being made? 5-3. Photo D.

B. Listen to more of the tape to answer the following questions.

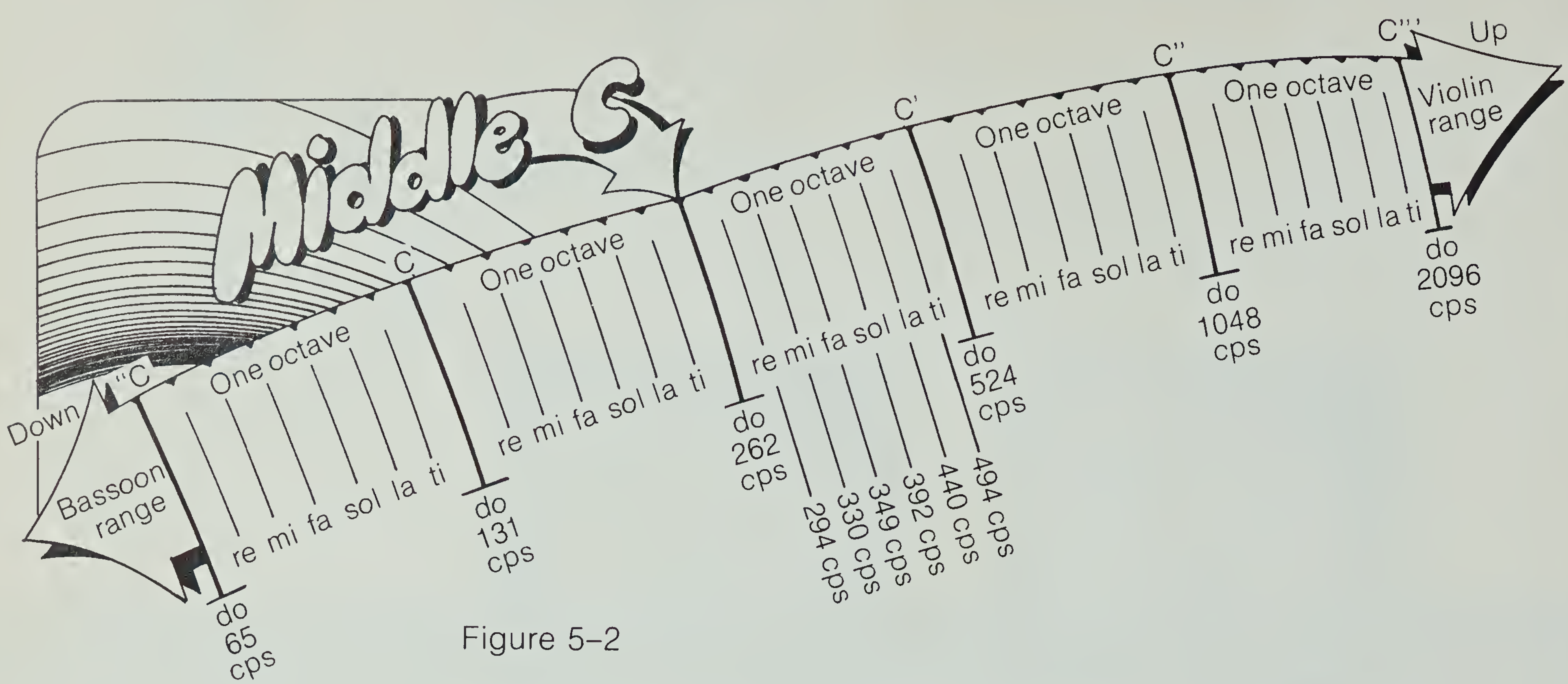


Figure 5–2

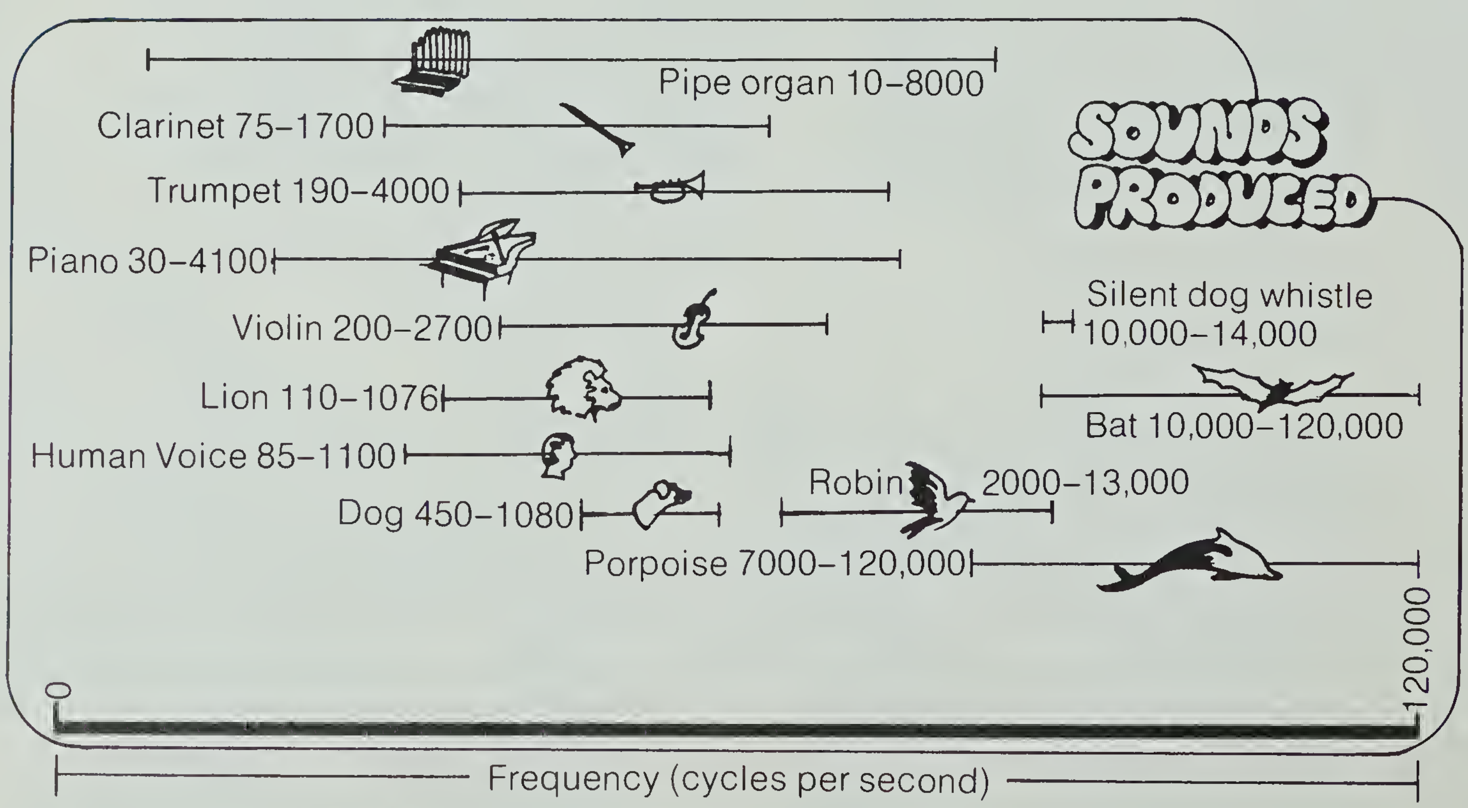
5–4. What was the highest note sung by the soprano? According to Figure 5–2, what was its frequency?
5-4. 1048 cycles per second

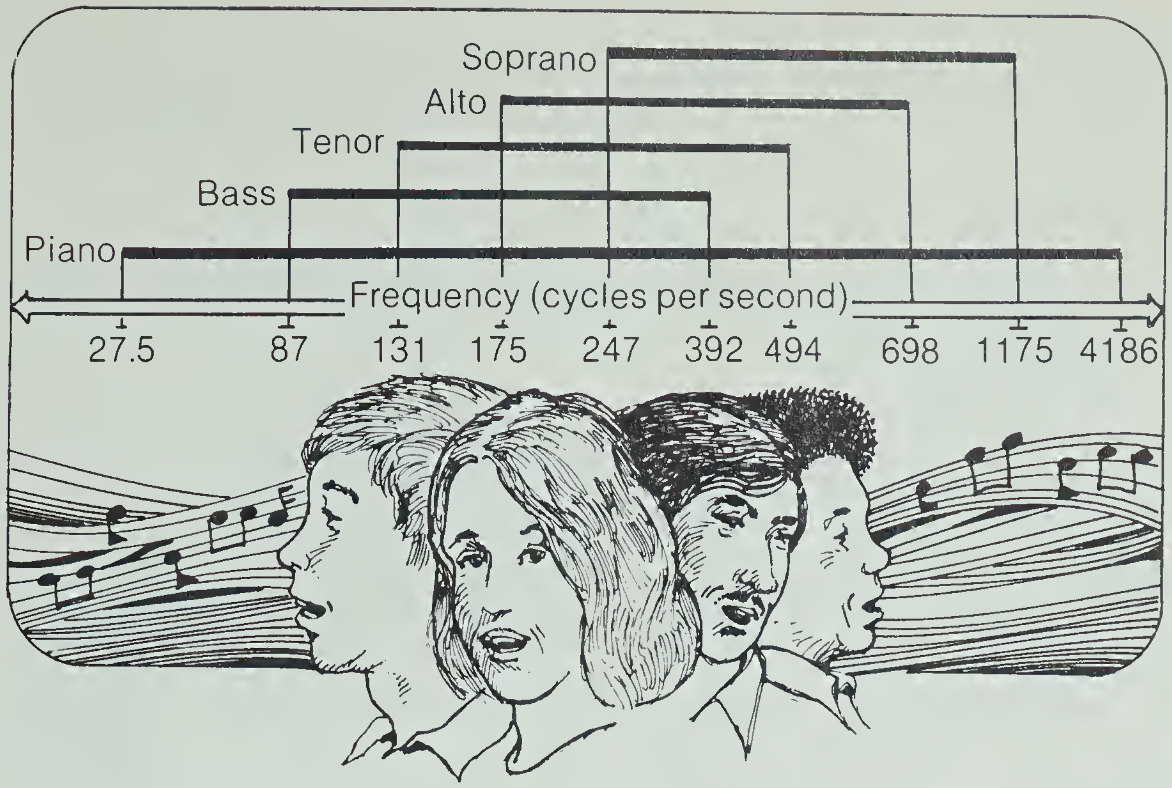
5–5. What was the lowest note sung by the bass? What was its frequency? 5-5. 65 cycles per second

5–6. What are the highest and lowest notes you can sing?
5-6. Answers will vary.

5-7. Answers will depend upon responses to Question 5-6.

5–7. What are their approximate frequencies?





✔ 5–8. Approximately what is the range of sound frequencies that can be sung by the human voice?

5-8. Approximately 85 to 1100 cycles per second.

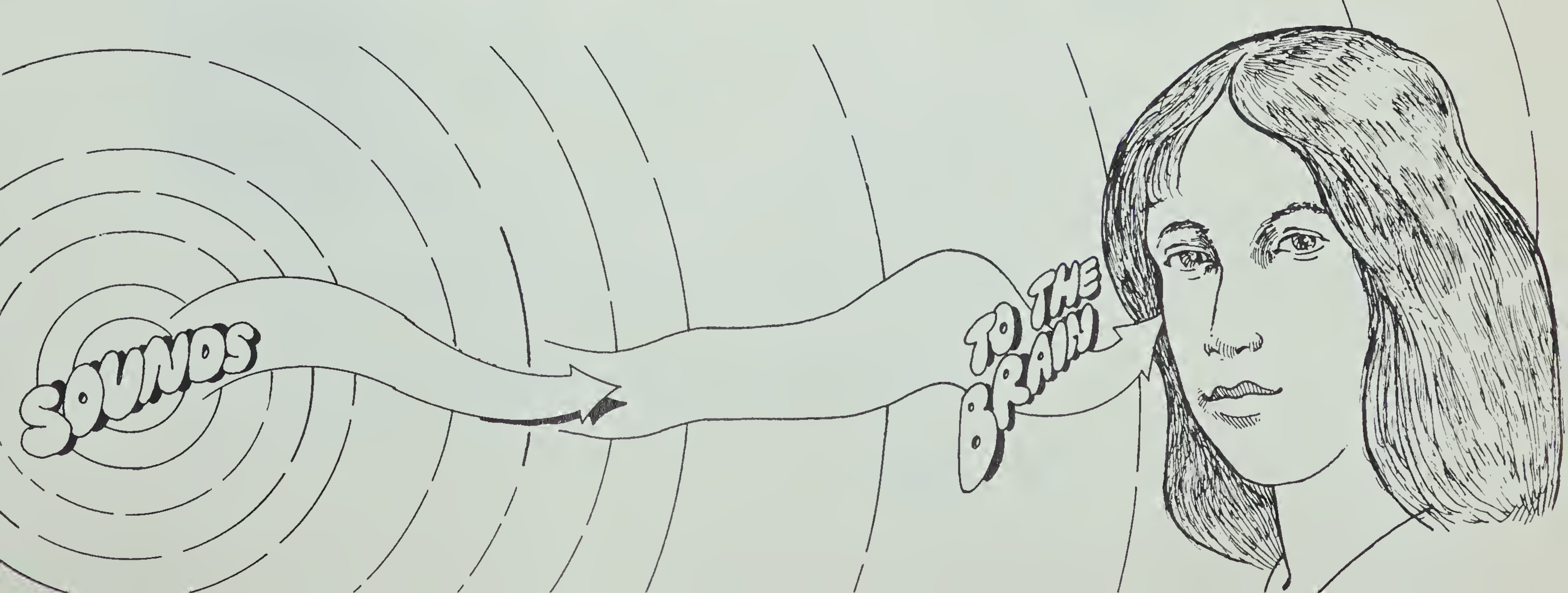
✔ 5–9. Is your range most like that of a soprano, alto, tenor, or bass? 5-9. Answers will vary.

The highest sound the human voice can produce is about 1200 cps. The lowest sound a bird can make is about 2000 cps, yet people imitate bird calls. They do this by whistling.

ACTIVITY EMPHASIS: The human ability to hear a wide range of frequencies; the parts of the ear and the function of each part.

Hearing Sounds

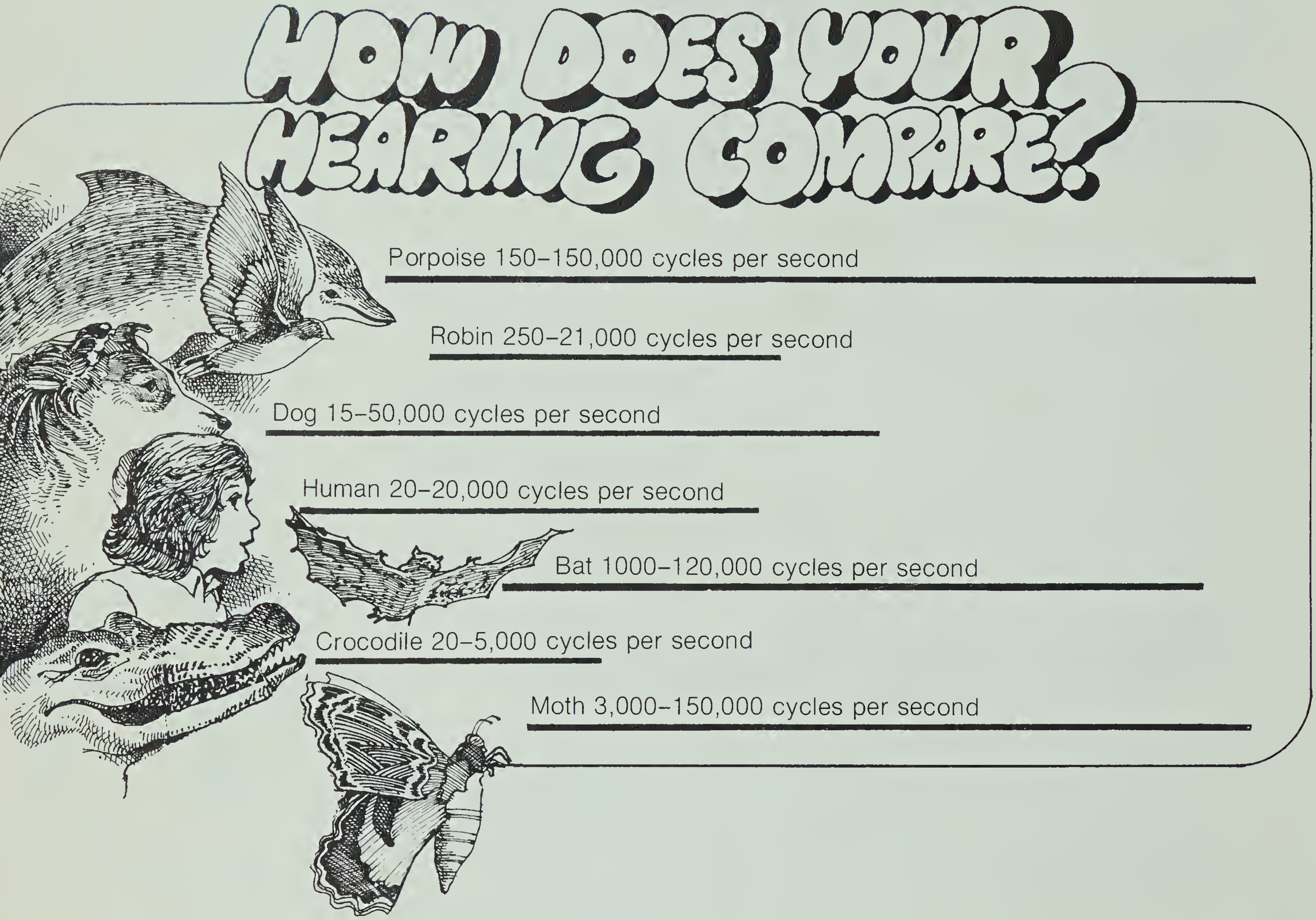
Every sound you hear is made by a vibrating object. This goes for tuning forks to squeaking doors. The vibrations of the object disturb the air, causing sound waves. When the sound waves hit your ears, the inside parts of the ear also vibrate. Your brain interprets these vibrations as sound.



MATERIALS PER STUDENT UNIT
cassette tape for *Sounds of Music*
cassette tape player, preferably with earphones

Do you hear *all* sound waves that are sent out? Or do your ears pick up only certain frequencies? How does the ear work? These questions are explored in this activity. You will need the following items:

cassette tape for *Sounds of Music, Activity 6*
cassette tape player



✔ 6–1. Listen to the tape. What is the highest frequency in cycles per second you can hear on the tape?
6-1. Answers will vary.

✔ 6–2. What is the lowest frequency you can hear on the tape?
6-2. Answers will vary.

✔ 6–3. What are some possible reasons why you cannot hear higher or lower pitched sounds than you do?
6-3. Individual differences related to age, sex, and physical makeup; the results of being in a noisy environment.

★ **6–4. Do men and women generally differ in hearing ability? If so, how?** 6-4. Yes. Women's hearing ability generally does not decrease over the years as much as men's.

★ 6–5. How does a person's hearing compare with that of an average dog? 6-5. Dogs can hear much higher frequencies.

How are sound waves coming at you from all directions interpreted by your brain as "sound" – musical or noise? What part do the ears play?

Ears are not much to look at on the outside. But behind the flaps of skin and cartilage lies a delicate structure. It is wonderfully adapted to hear, among other things, the sounds of music.

The school biology department probably has a model of the ear that would be helpful to students in this activity.

The three major parts of the human ear are the outer, middle, and inner ear.

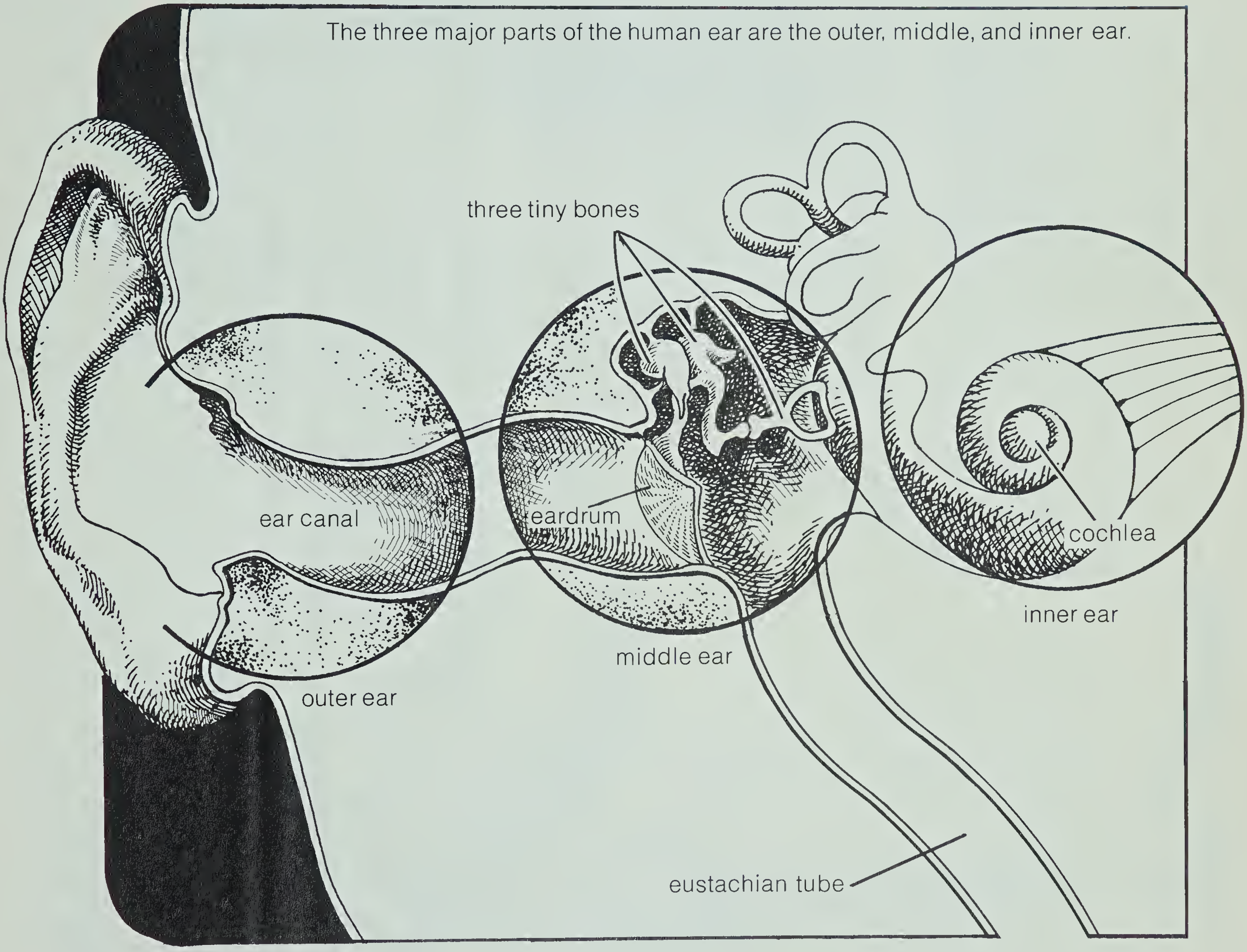
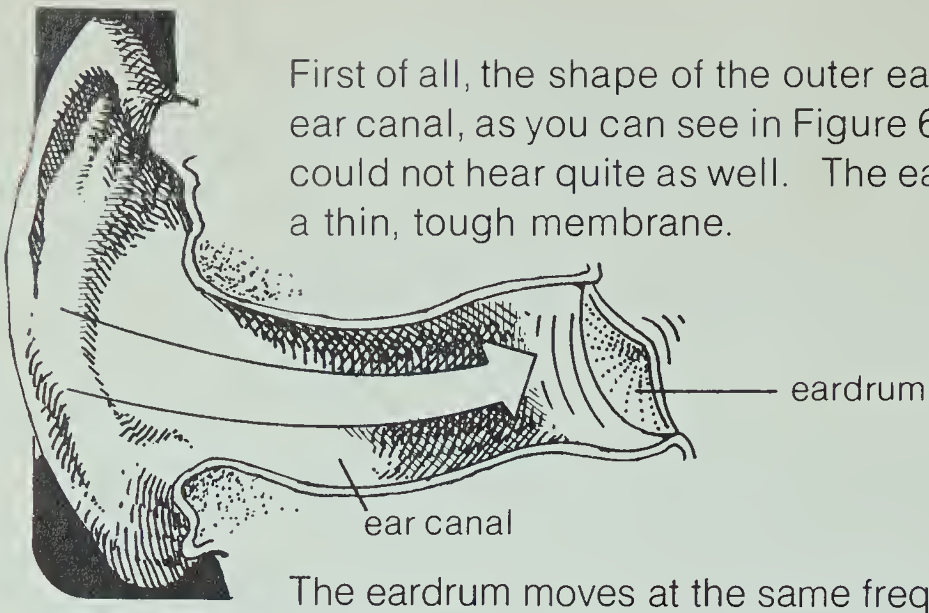


Figure 6–1

The inside of the ear has to be very sensitive. Think of the problem. Disturbances in the air caused by sound waves are incredibly small. If these changes are to be detected, they must produce an effect on nerves inside the ear. These nerves must then send the message to the brain. How does this happen?

First of all, the shape of the outer ear helps funnel sound into the ear canal, as you can see in Figure 6–1. Without these flaps you could not hear quite as well. The ear canal ends at the eardrum, a thin, tough membrane.



The middle ear is connected to the back of the throat by the eustachian tube. This tube equalizes the air pressure on both sides of the eardrum. At high altitudes, the pressure in the middle ear is greater than the external pressure. The "popping" sound in the ears happens when the pressure in the middle ear is reduced to the external pressure.

The hearing reduction often accompanying a head cold is a result of the blocking of the eustachian tube.

The eardrum moves at the same frequency as the air disturbances that strike it. The amount it moves depends on how strong the air disturbances are. But even a loud noise causes only tiny movements of the eardrum.

✔ 6–6. What structure separates the ear canal from the rest of the ear? 6-6. The eardrum.

What happens to the sound after it causes the eardrum to vibrate? First, the disturbance passes through the middle ear. Figure 6–2 shows what happens to the sound wave in the middle ear. The drawing of the three bones is greatly enlarged. In your head, the bones take up about the space of a cube of sugar.

The middle ear not only passes the sound along. It does something else. Because the compressions of the sound wave are not strong enough, the middle ear makes larger, or *amplifies*, the strength of the sound wave.

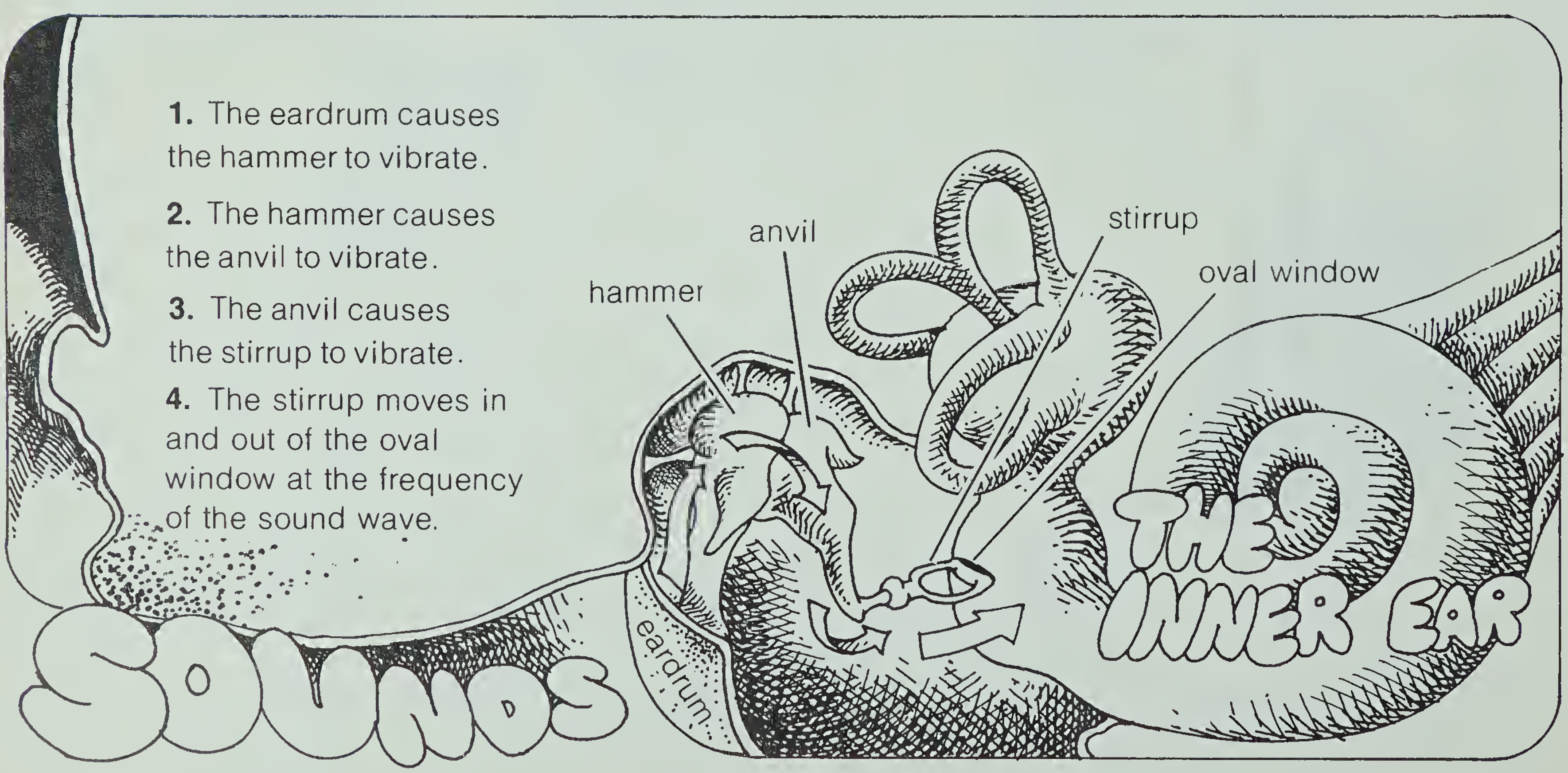
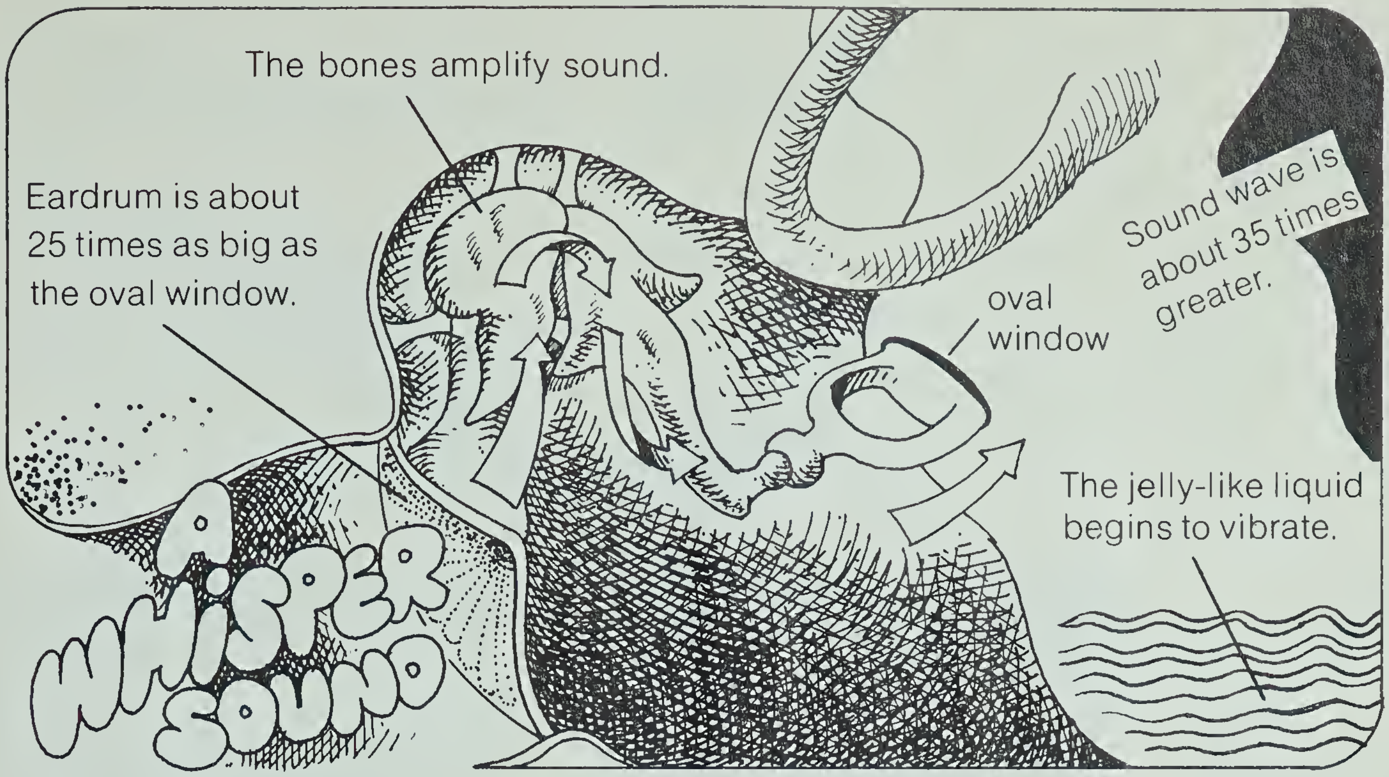


Figure 6–2



From the middle ear the sound goes to the inner ear. Inside the inner ear, the vibrations pass along a spiral, fluid-filled tube called the cochlea (COCK-lee-ah), shown in Figure 6–3. One part is filled with nerves. Just how the cochlea works is not entirely known. But it is known that different parts of the cochlea are sensitive to sounds of different frequencies.

The vibrations passing along the cochlea cause resonance in various parts of that organ. At its beginning, the cochlea resonates to high frequencies; toward the end it resonates to lower frequencies.

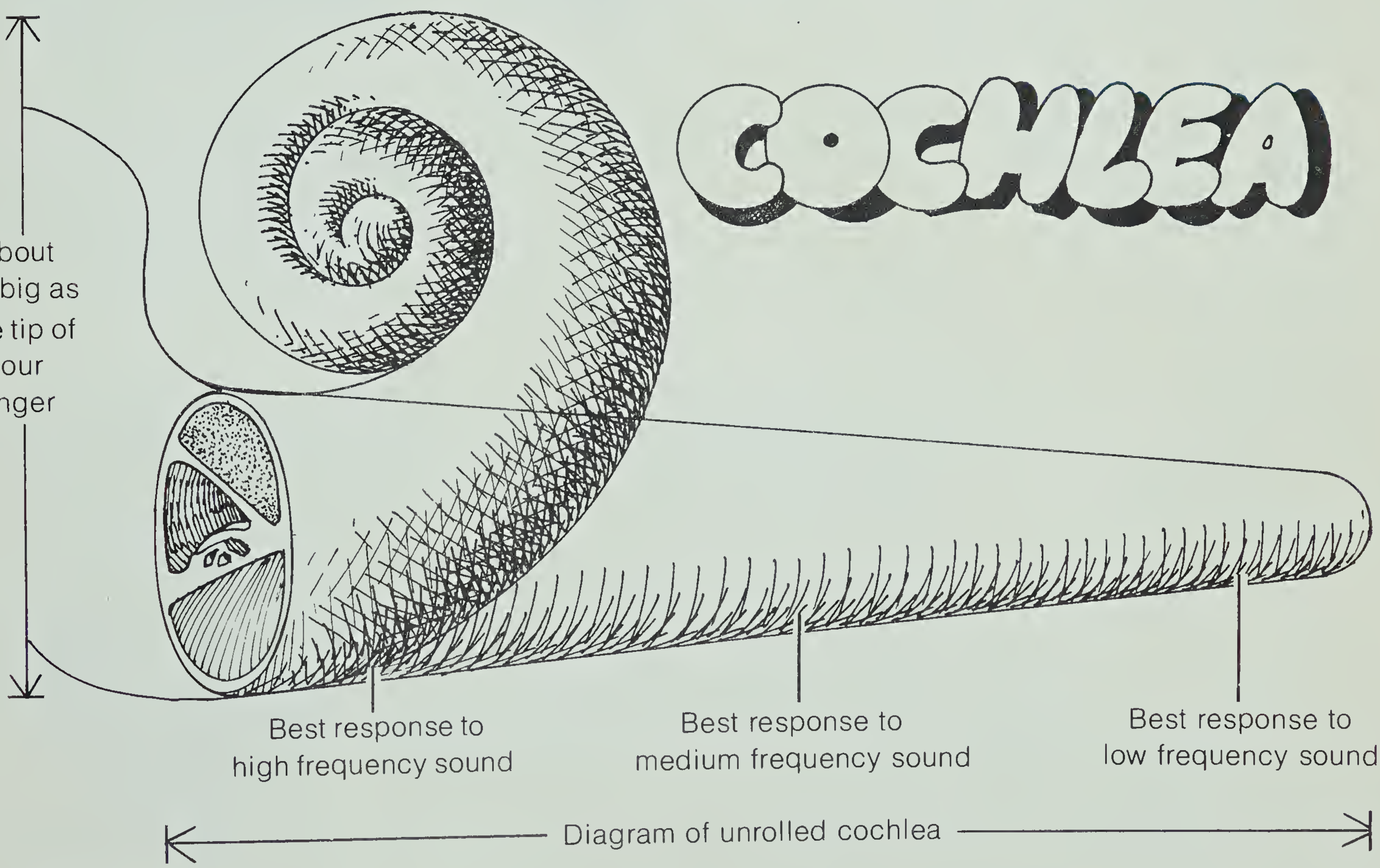
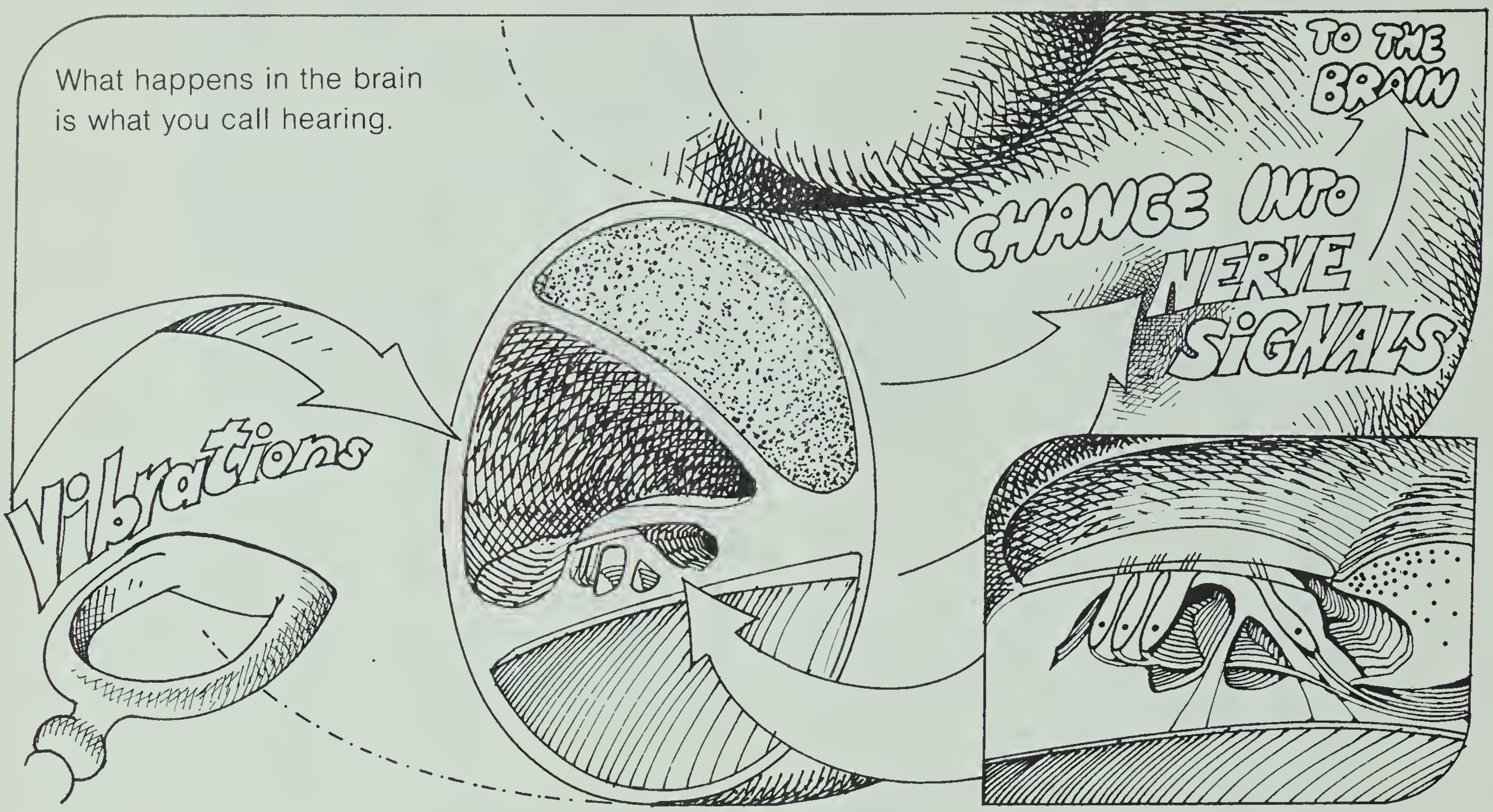


Figure 6–3

Inside the cochlea is the most complicated of all the pieces of machinery involved in hearing. This is the organ of Corti. The organ of Corti relays to the brain the frequencies and intensities of the sound waves.



6-7. The inner liquid transmits the vibrations and stimulates the organ of Corti. Nerve impulses are relayed to the brain.

✓ 6–7. In your own words describe what happens to sound vibrations once they reach the oval window of the inner ear.

Thus, the sound of music which enters your ear is "heard" an instant later by your brain, after a complicated trip through air, bones, fluids, and nerves.

You can tell the difference between a piano and a violin playing the same note. Or the difference between a telephone ring and that of an alarm clock. Or your mother's voice from that of almost any other woman.

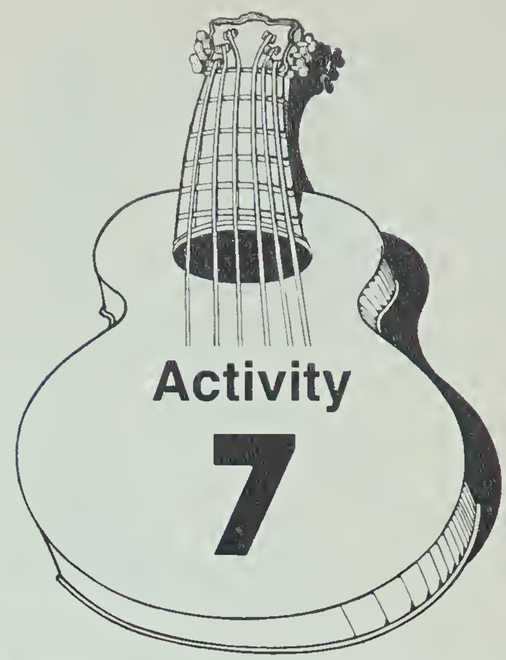
The really fascinating part about hearing is not yet understood. When so many different sounds come through your ears, how does your brain tell which is which? And how does your brain "listen" to some sounds and "tune out" others. Some of these questions may be answered during your lifetime, but they haven't been answered yet.

6-8. Sound vibrations strike the eardrum and are amplified by the bones of the inner ear. The amplified vibrations are detected by the cochlea and transmitted as nerve impulses to the brain.

✓ 6–8. Describe the path a sound compression takes from the outside of your ear to your brain.

ACTIVITY EMPHASIS: Students investigate how the air column of wind instruments must change to produce different pitched sounds.

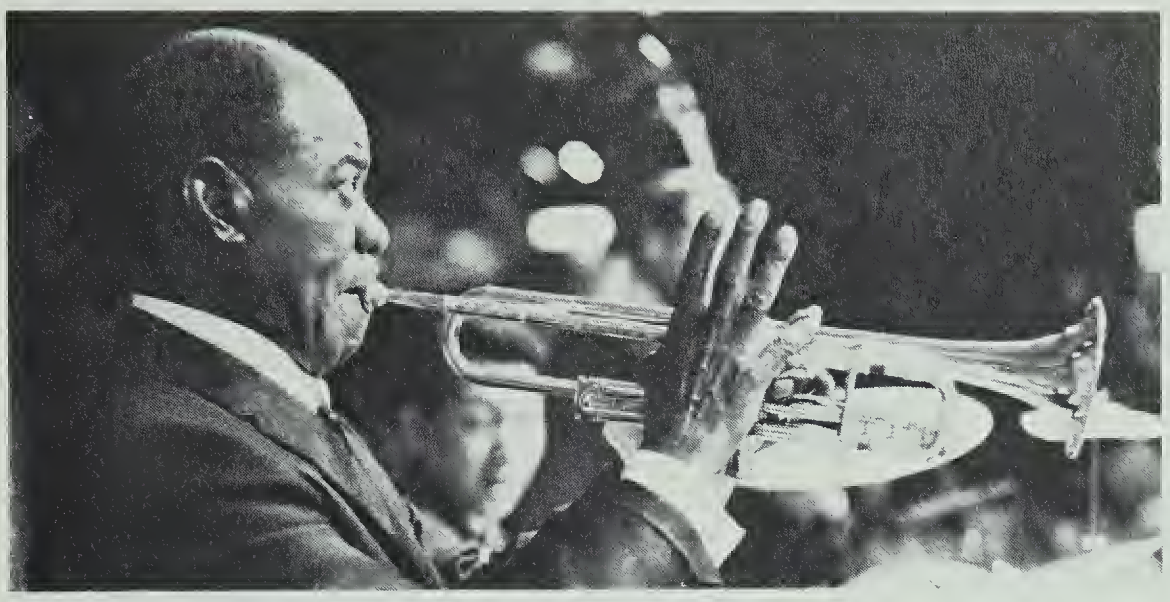
Columns and Horns



What is more spectacular than the sound of a trumpet? Or the sliding tones of a trombone? Or the call of a bugle? Yet all of these instruments have simple mouthpieces. There is nothing inside the mouthpiece to vibrate.

MATERIALS PER STUDENT UNIT
soft drink bottle, empty
water

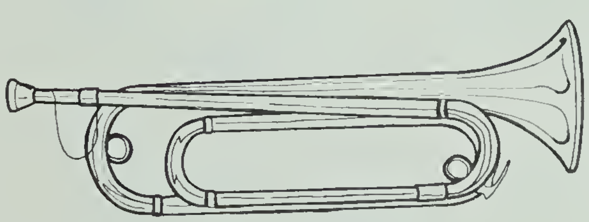
An actual brass instrument in the classroom would be useful to students in doing this activity.



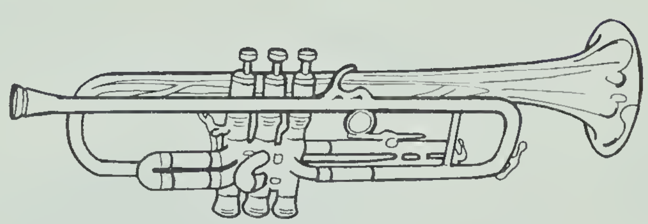
Louis Armstrong

What object, then, vibrates to produce these musical sounds? For one thing, the player's lips vibrate. But the buzzing noise you can make by holding your lips together and blowing air doesn't sound very musical! Combine lip vibrations with a brass instrument, however, and you have musical sounds.

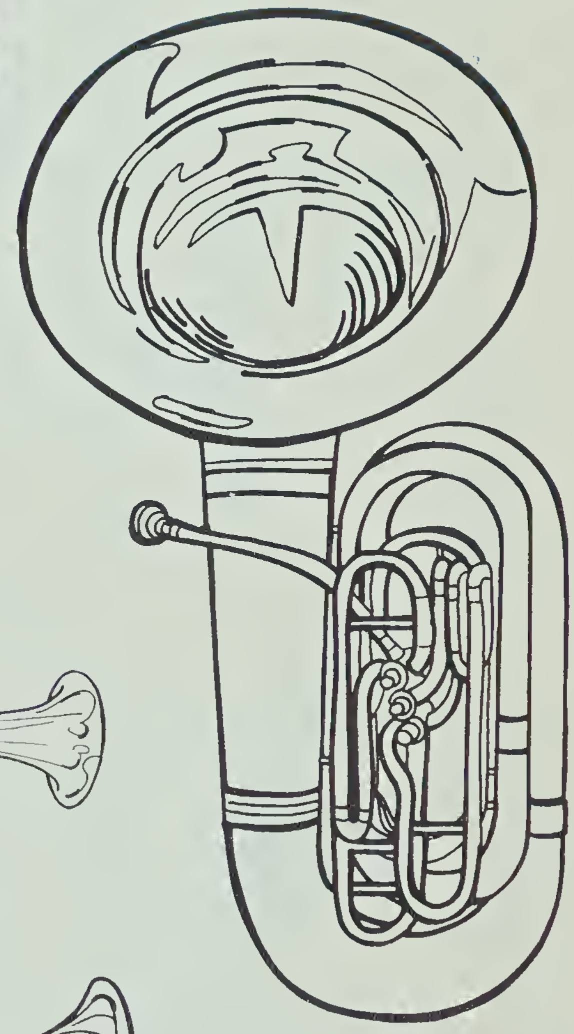
Brass Instruments



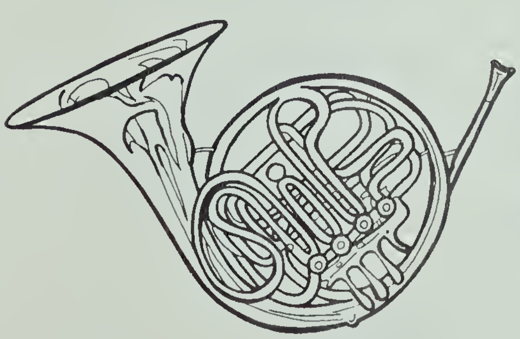
Bugle



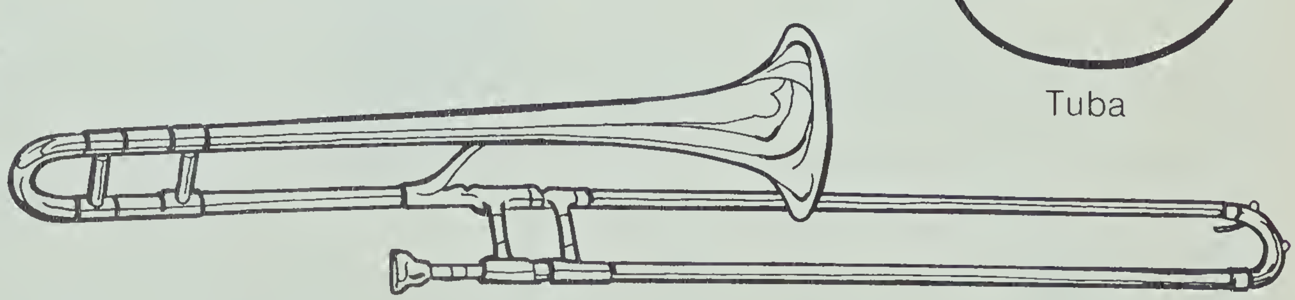
Trumpet



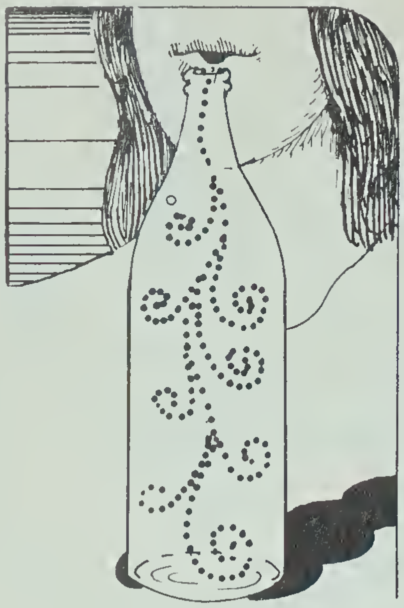
Tuba



French Horn



Trombone

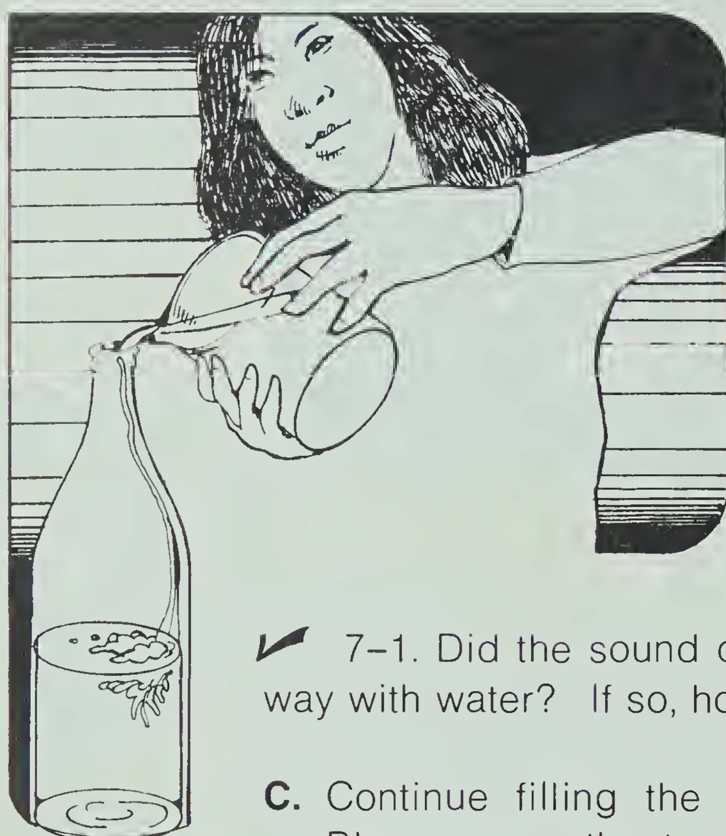


This investigation will show you how lip vibrations can produce sound. You will need the following items:

empty soda bottle
water

A. Blow across the mouth of the empty soda bottle softly. With a little practice you should be able to make two or three notes.

B. Fill the bottle halfway with water. Now blow across the bottle again.



7–1. Did the sound change when you filled the bottle halfway with water? If so, how? 7-1. Yes. The sound became higher.

C. Continue filling the bottle with small amounts of water. Blow across the top of the bottle after each addition of water.

7–2. What happened to the sound each time you added water? 7-2. The sound became higher.

7–3. How can you produce different sounds by blowing across the top of the bottle? 7-3. By varying the amount of water in the bottle.

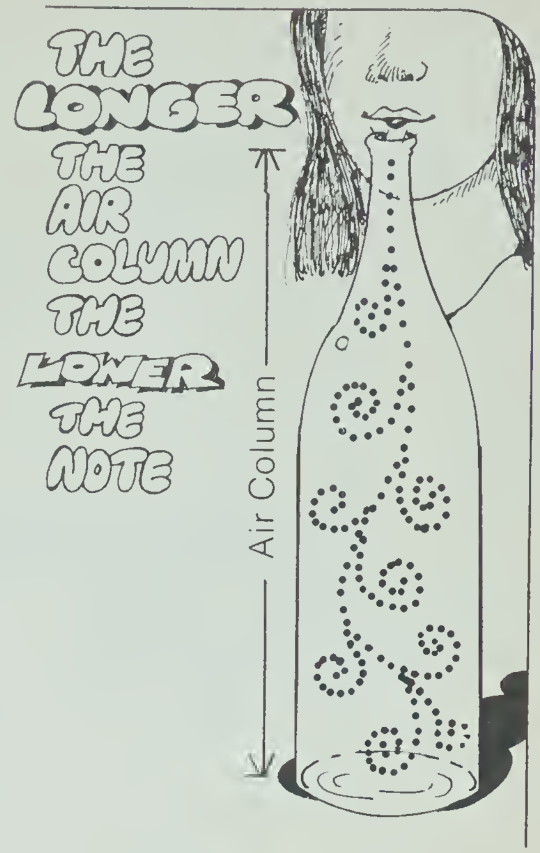
When you blow across an empty bottle, you cause the air inside the bottle to vibrate. The vibration of the air produces sound. But the air inside the bottle, or *air column*, vibrates at only a certain frequency. This is called its *natural frequency* of vibration.

7–4. What did filling the bottle halfway with water do to the length of the air column? 7-4. It halved the air column.

Each time you added water to the bottle, you changed the length of the air column. You made the air column shorter. Therefore you changed the natural frequency of vibration. The shorter the air column, the higher the note that you can produce. The longer the column, the lower the note. That is why you produced a different sound after each addition of water.

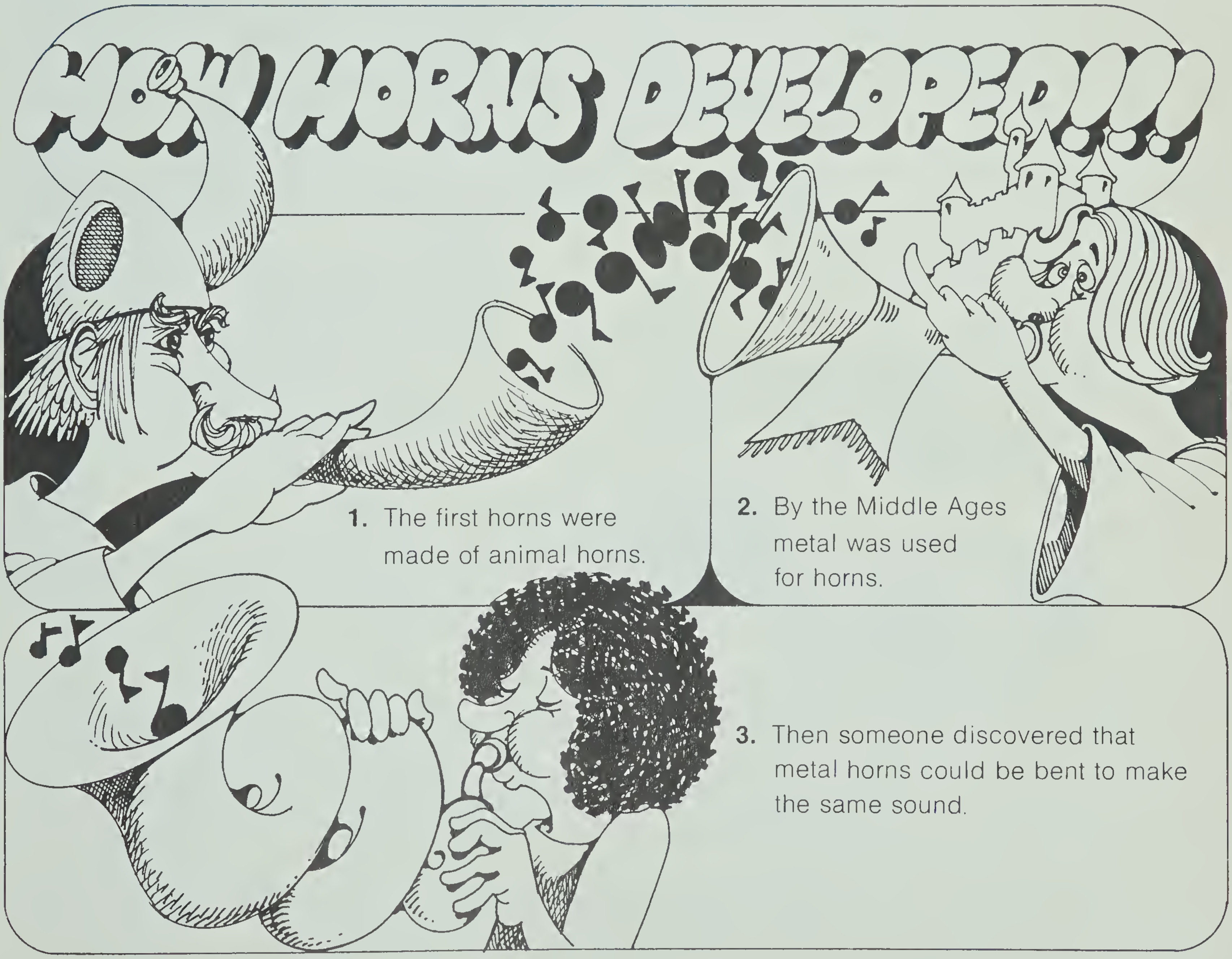
A musician can play several notes on a brass instrument without changing the length of the air column in the instrument. The player does this by changing the position and tension of the lips. Sometimes the tongue is used to change the flow of air into the instrument. This changes the frequency of the vibrations.

There are five to six notes that can be played at any one length of the air column. Often the lowest note is physically impossible to blow. So the player can play only five notes. These are the so-called "bugle notes."



7–5. The length of the vibrating air column of a bugle cannot be changed. Why are bugle calls written for only five notes?

7-5. These five notes are the only ones possible to play on a bugle.



Look at a bugle—both regular and uncoiled—in Figure 7–1.

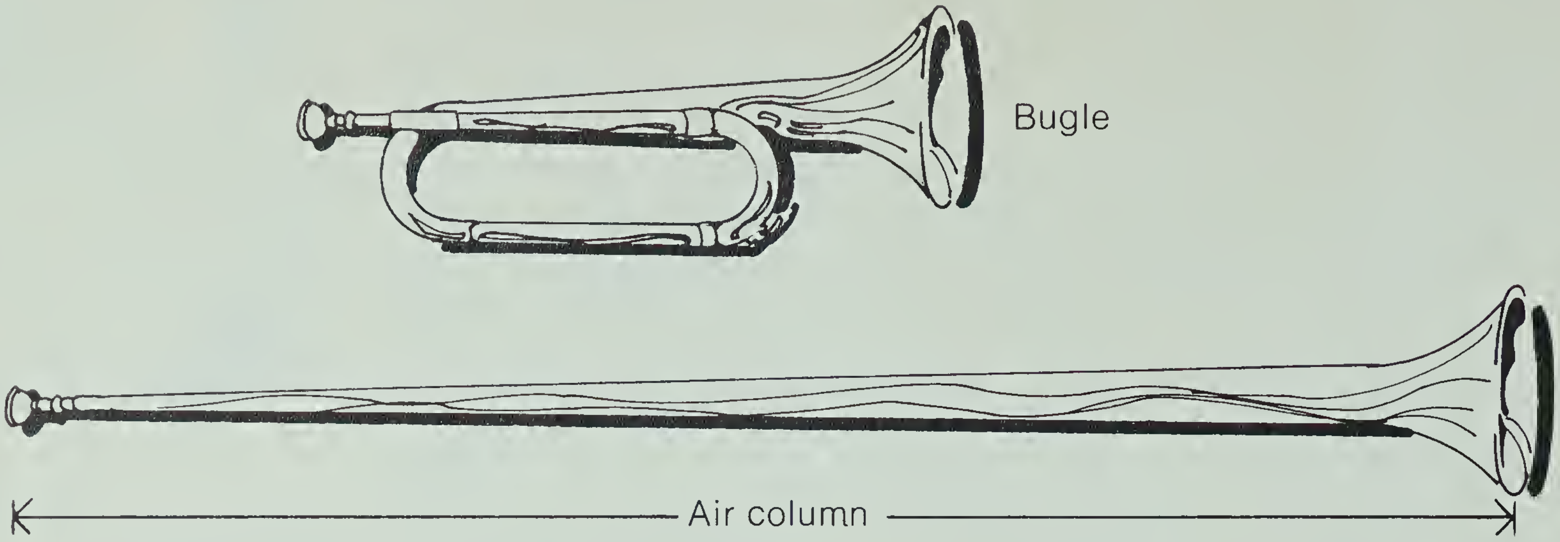


Figure 7–1

The air column which vibrates to produce sounds goes from the mouthpiece to the flared bell at the other end. The length of the air column cannot be changed by a bugler.

Now look at a trumpet. The trumpet has three valves. Pressing down each valve opens a coil, which lengthens the air column.

Figure 7–2 shows the relative length of the air column in a trumpet when all the valves are closed. Then, when one valve is open.

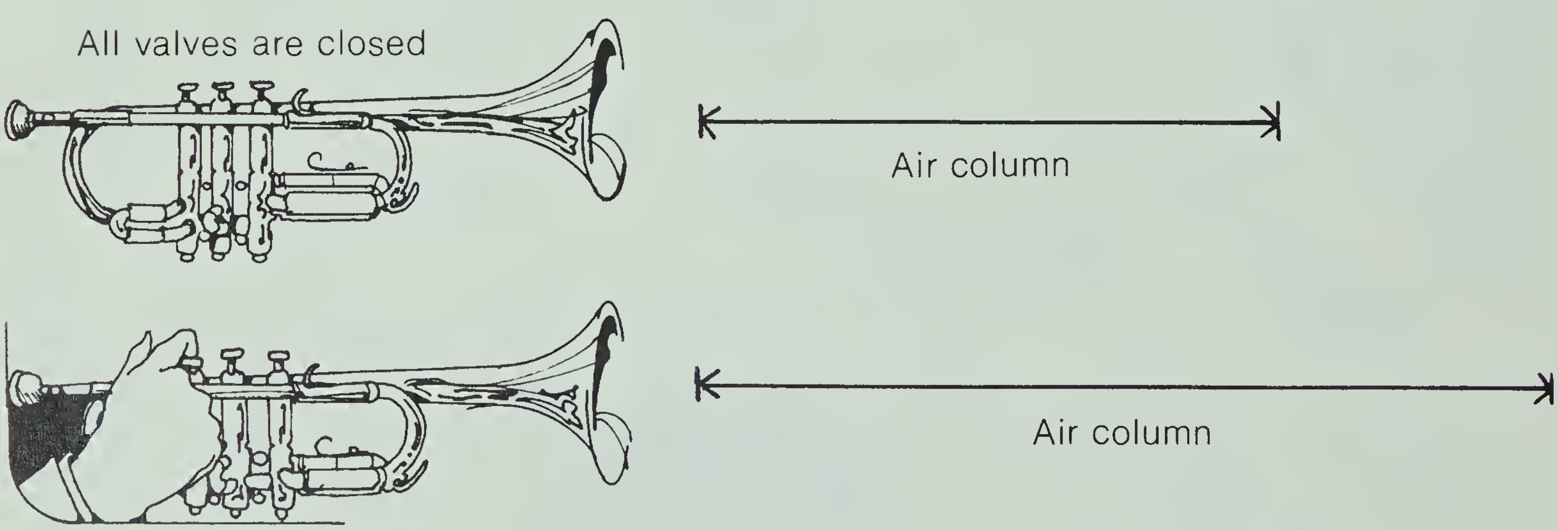


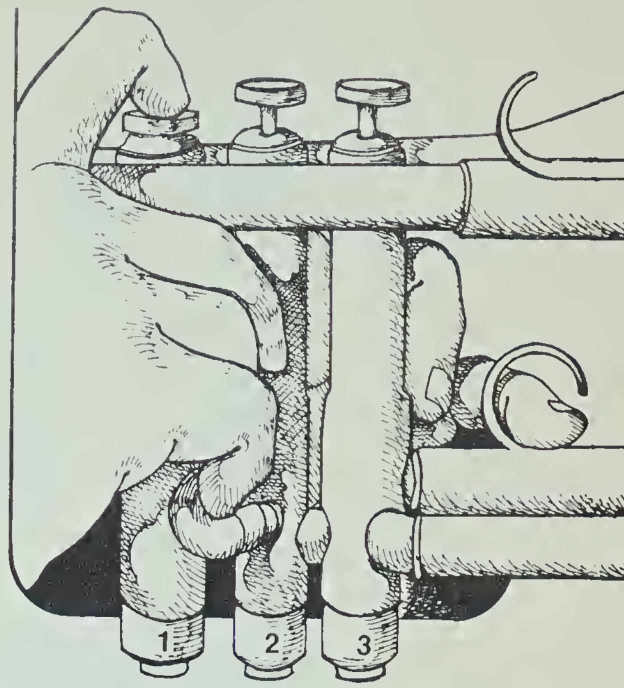
Figure 7–2

✔ 7–6. What happens to the length of the vibrating air column when one valve is open? 7-6. It gets longer.

✔ 7–7. Which position would produce a lower note—one valve open or two valves open? 7-7. Two valves open.

7-8. Eight possible ways: (1) All valves closed; (2) all valves open; (3-5) any one valve open and two closed; (6-8) any two valves open and one closed.

A trumpet player can make about 35 to 40 notes. This makes sense when you realize that the player can blow about 5 notes, or frequencies, for each length of the air column.



7–8. How many possible ways can you change the length of the air column in a trumpet? Here are two ways. Find the others.

1. Valves 1, 2, and 3 closed.
2. Valve 1 open; valves 2 and 3 closed.

The trombone uses a different system to change the length of the vibrating air column, as shown in Figure 7–3.

★ 7–9. How does a trombone player change the length of the air column? 7-9. Changing the position of the slide alters the length of the air column.

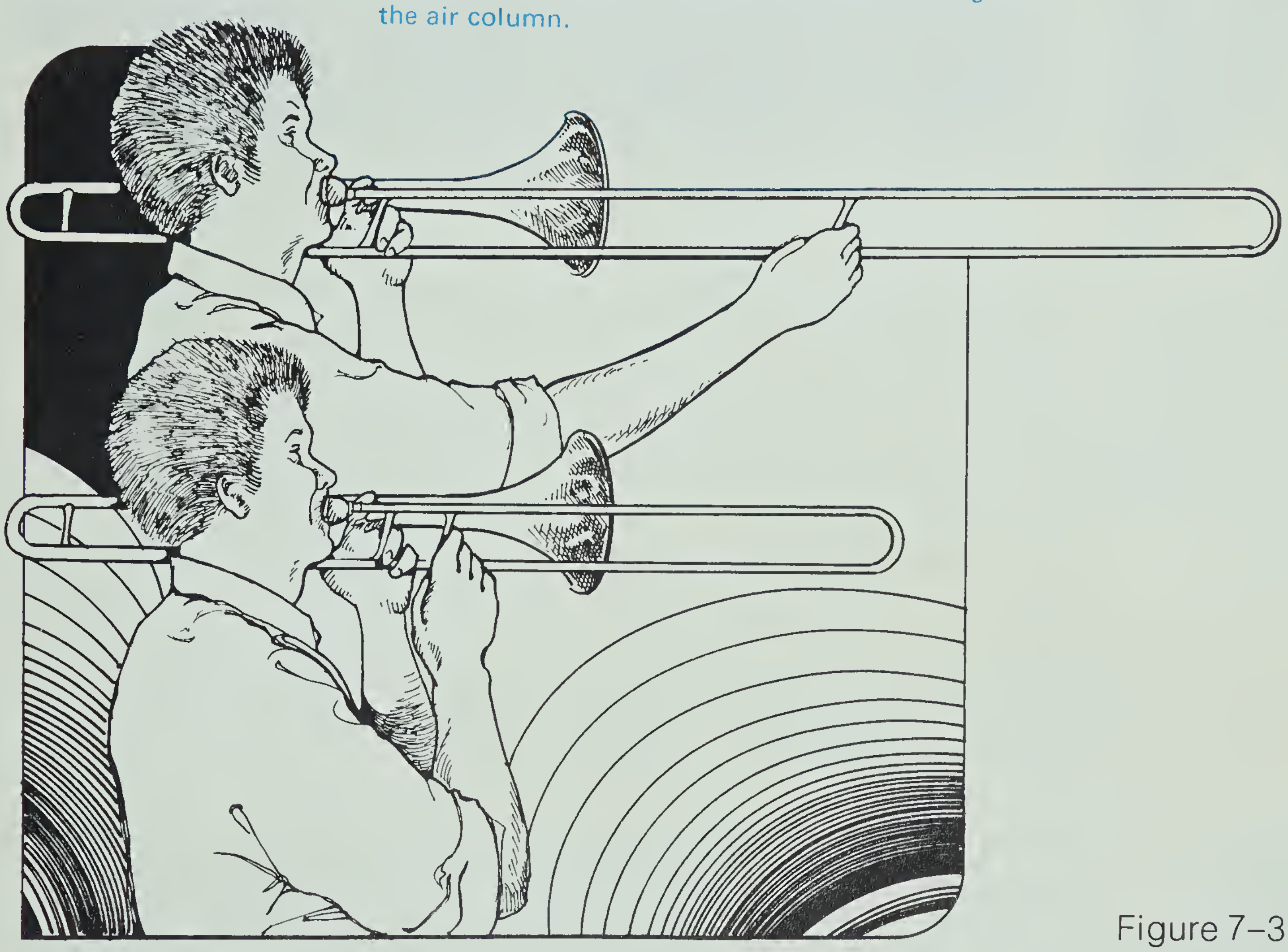


Figure 7–3

7–10. A trombone player can "slide" gently from one note on the scale to another. Explain how this could be possible.

7-10. All possible lengths of the air columns can be produced.

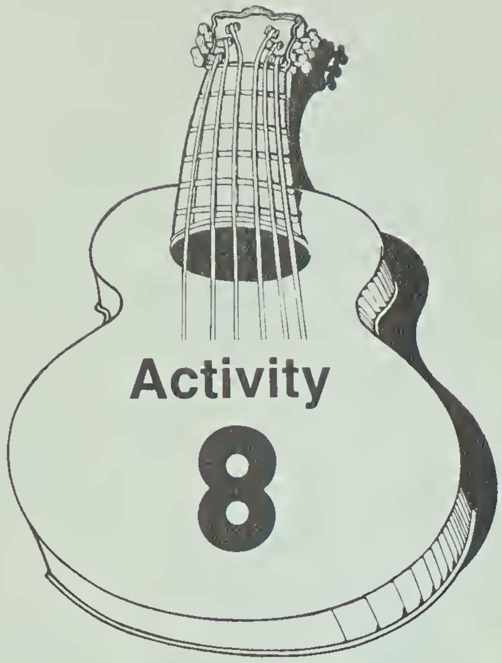
7–11. Which appears to have a longer air column—trumpet or trombone?

7-11. Trombone.

7–12. Which instrument can play lower notes—trumpet or trombone?

7-12. Trombone.

ACTIVITY EMPHASIS: Students make a "soda straw" woodwind to see how woodwinds produce different sounds.



Vibrating Reeds

Benny Goodman

MATERIALS PER STUDENT UNIT
2 plastic drinking straws
ruler, metric
scissors

Some wind instruments do not need the vibrations of the player's lips to create a sound. These are the *woodwind instruments*. Originally, all woodwinds were made of wood or bamboo. Today, some woodwinds are made of metal and plastic as well as wood. Having an actual woodwind instrument in the classroom would be useful for this activity.

✔ 8–1. Where does the wind needed to play woodwinds come from? 8-1. From the lungs of the player.

As the player blows into the instrument, his or her breath causes the air column in the instrument to vibrate.

✔ 8–2. According to Figure 8–1, what are two ways in which the air column in a woodwind can be changed? 8-2. By changing the length of the pipe by fingering the holes or by using pipes of different lengths.

★ **8–3. How does changing the length of the air column affect the sound produced? *(Review Activity 7 if you have trouble with this question.)*** 8-3. The longer the air column the lower the note; the shorter the air column the higher the note.

Woodwind makers found that if they inserted a thin piece of wood in the mouthpiece, they could play more interesting tones. The piece of wood is called a *reed*. Blowing into the mouthpiece makes the reed vibrate. The vibrating reed causes the air column in the instrument to vibrate.

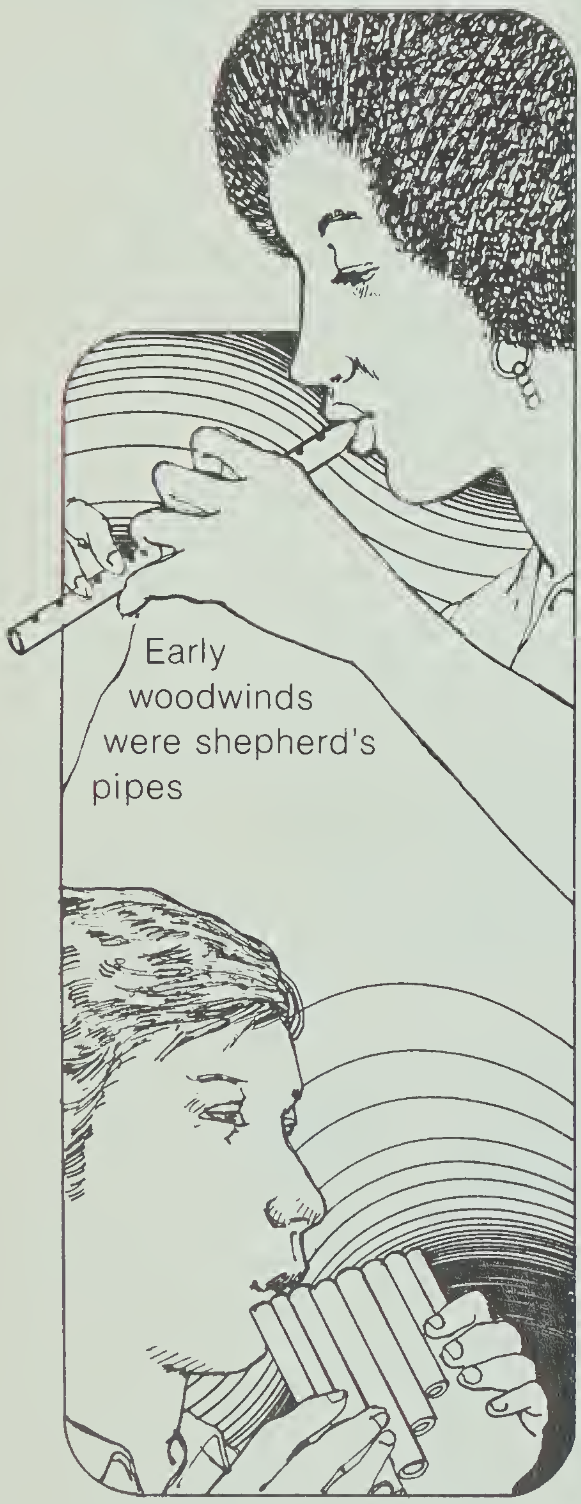
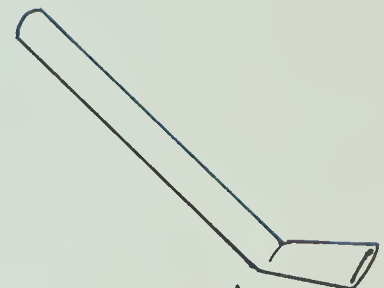


Figure 8–1

Getting a suitable sound from a "soda straw" woodwind takes patience and practice. Encourage the students to stick with it. They should blow through the straw firmly but smoothly.

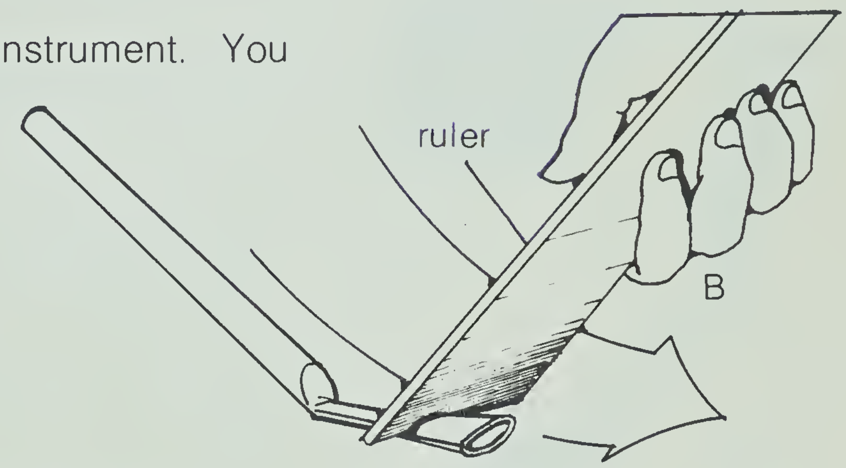
Woodwinds with reeds



Clarinets, oboes, saxophones, and bassoons use reeds in the mouthpiece.

You can make a simple version of a woodwind instrument. You will need these items:

2 plastic drinking straws
ruler
scissors

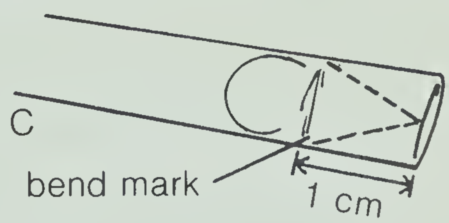


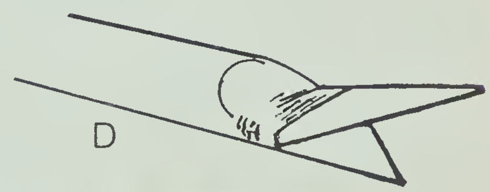
A. Bend the straw about 1 cm from one end.

B. Push down HARD with edge of ruler to flatten the end.

C. Cut on the dotted lines.

D. Finished end should look as shown.





E. Now play the "soda-straw clarinet." Put the cut end between your lips so that the bent mouthpiece is in your mouth. Blow gently but steadily. If you have trouble getting a loud sound, flatten the end again (Steps A and B).

You still may have trouble getting a loud sound, but even a very soft sound made on your soda straw will give you the idea.

✓ 8–4. What vibrates to make the sound?
8-4. The pointed tip of the straw vibrates.

✓ 8–5. Can you change the pitch by blowing softer or harder? Try it! 8-5. Yes. Blowing harder causes the tip to vibrate faster.

F. Make a second soda-straw clarinet. Compare the tones produced by the two straws.

8–6. Do both straws produce the same pitch?
8-6. No, unless they are both exactly the same length.

8–7. What is the length, in centimetres, of the air column of your soda straw clarinet? 8-7. Answers will vary.

8–8. How could you change the length of the air column?
8-8. By cutting the straw shorter.

G. Take one of the straws and blow a steady note. *While blowing,* cut off a 2 cm length with your scissors until the straw is about 5 cm long.

8–9. What happens to the sound produced as the straw's length is shortened? What happens to the length of the air column?
8-9. The sound becomes higher. The length of the air column becomes shorter.

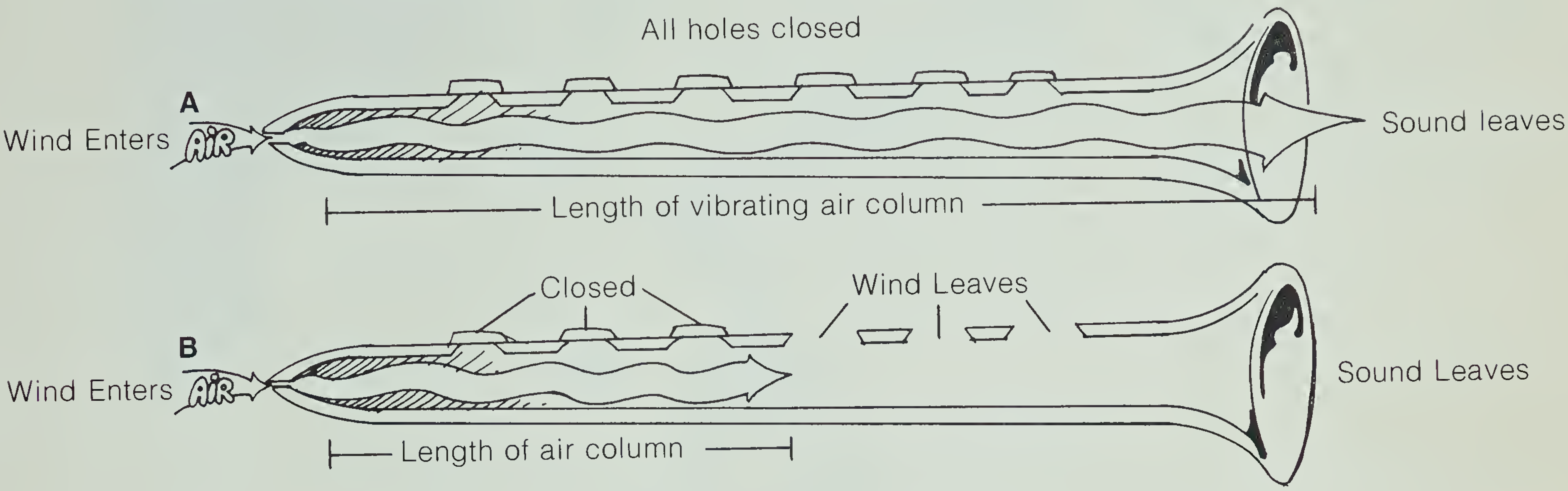
The sound of a note, then, depends on (1) how the straw's end is cut and flattened, (2) how hard you blow, and (3) the straw's length, which is the length of the air column. All three variables are important with woodwinds.

The flattened end of the straw acts like a reed. In woodwinds which use reeds, the reed is not part of the instrument as it was in your straw. (See Figure 8–2.) As you found with the straw, the player needs to control the vibrations of the reed with his or her lips. Getting a good sound takes practice. In the lips of beginners, reed instruments squeak a lot!

Figure 8–2

You can produce many different notes on a woodwind by opening and closing holes in the side of the air column. An ordinary clarinet has 24 holes that may be opened or closed to change the length of the column of air.

Here is a simple example of how you can change the length of the air column in woodwinds. Suppose you had a woodwind instrument with only six holes—perhaps a homemade pipe. Figure 8–3 shows the length of the air column when (A) all six holes are closed and (B) when the last three are open.



In (A) all the holes are closed, so the vibrating air column is the whole length of the instrument. In (B) the last three holes are open. This acts as though the tube has been shortened. The wind leaves from the open holes. The length of the vibrating air column is now about one half the total length of the instrument.

Figure 8–3

The most common woodwind in a band is the clarinet. Bands also include saxophones and oboes.

Two woodwinds used in orchestras do not have reeds — flute and piccolo. Both are made of silver metal and consist of tubes closed at one end. They are played similar to the way you "played" the water-filled bottle in Activity 7. The recorder is an early flute-type instrument that has become popular again.

Woodwinds without reeds

ACTIVITY EMPHASIS: The effects of the length, tightness, and thickness of string on the pitch of sounds produced by stringed instruments.

Music of Strings

No matter what kind of music you like—pop, country, or classical—stringed instruments are probably part of it. The violin is considered the backbone of the orchestra. And from Bob Dylan on—the music of strings is basic to pop music.

You may think of an electric guitar when strings are mentioned. But there are many instruments that use vibrating strings to produce sounds—violins, banjos, harps, guitars, cellos, and double basses are some.

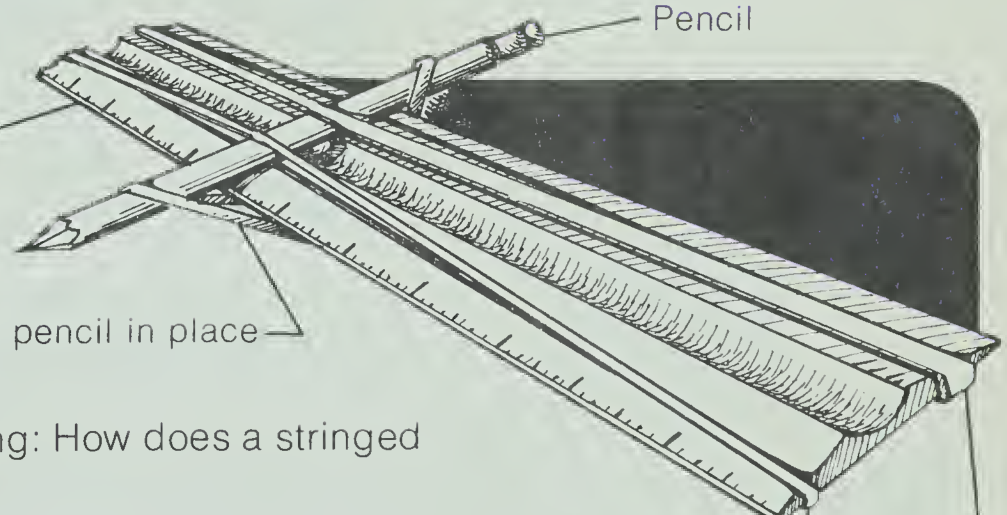
Having an actual stringed instrument in the classroom would be useful in this activity.

In this activity you'll see how vibrating strings can produce different notes. To do it, you'll need a stringed instrument. If possible, get a banjo, guitar, ukulele, or similar instrument to use.

MATERIALS PER STUDENT UNIT
ruler
pencil
3 rubber bands (two the same length, one thick and one thin)
guitar, violin, or piano (optional)

If you can't use a real stringed instrument, make one for yourself or use one that someone else has made.

As a last resort, you can do this activity using a "musical instrument" made from a ruler, a pencil, and three rubber bands as shown. Try to get two rubber bands of the same length, one thick and one thin. The rubber bands need to fit fairly tightly on the ruler. The third rubber band is used to hold the pencil in place.



Here's the question you'll be investigating: How does a stringed instrument produce different notes?

A quick look at a real stringed instrument shows that not all its strings are the same. They have different thicknesses and sometimes different lengths. Some strings are also strung tighter than others.

✔ 9–1. What three factors might change the sound of a note on a string? 9-1. The length, thickness, and tightness (tension) of the string.

Effect of LENGTH of String

A. Select one string on your musical instrument. Find a way to change its length *without* changing its tightness. Find out what effect a string's length has on the sound of a note.

String A and B are actually the same length in the illustration. But the musician is holding down String B against the neck of the guitar. So the *effective length* of String B is different. The effective length is the part that vibrates when the string is plucked.

✔ 9–2. Which has a longer effective length—String A or B?
9-2. String A.

✔ 9–3. Which one of the following conditions of the strings did you *change* during this test? The other conditions should have stayed *the same*, or as close to the same as you can keep them.

1. String thickness
2. String tightness
3. String length

9-3. Condition 3: String length changed.

✔ 9–4. How did the sound of the note change when you shortened the string—without changing the string's tightness or thickness? 9-4. The note became higher.

The method you just used to see the effect of string length on sounds produced is a good way to do investigations. In order to see what effect length had, you kept the other two conditions of the string (tightness and thickness) from changing. That way, you were sure that whatever happened was because of a change in length. You should know, however, that although you tried not to change the tightness or the thickness, it's difficult to keep them *exactly* the same.

Effect of TIGHTNESS of String

B. Select one string on the musical instrument and tighten it *without* changing its length or thickness.

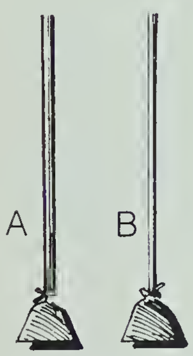
9–5. What condition did you change this time and which ones did you keep the same?
9-5. Tightness changed; length and thickness remained the same.

9–6. How did the sound of the note change as string tightness increased? 9-6. As tightness increased, the note became higher.

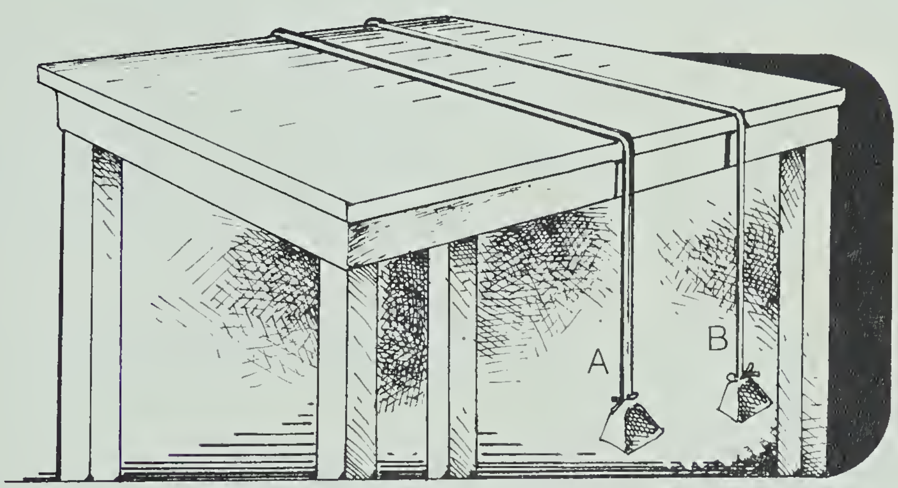
Effect of THICKNESS of String

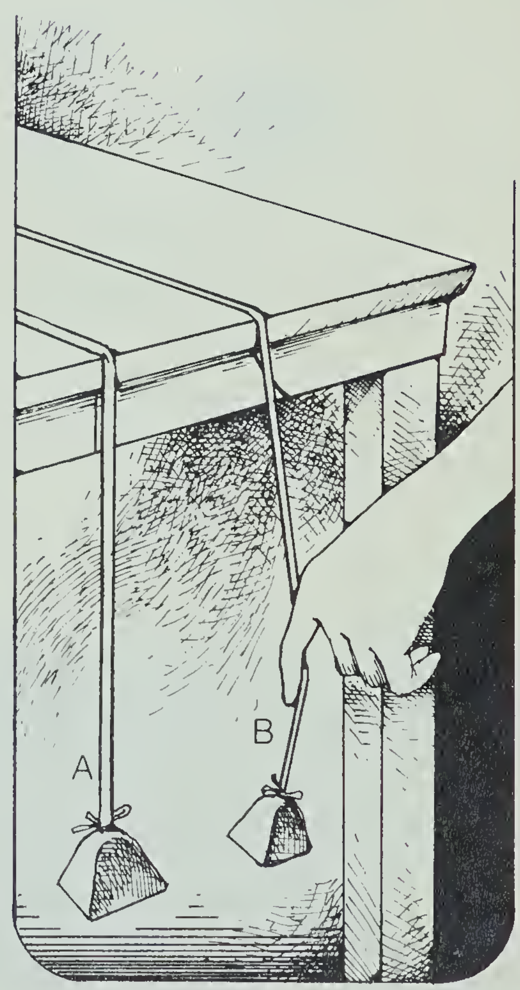
You need one thick and one thin string the same length. You can use some fishing line. You also need weights of equal size.

C. Tie equal-size heavy weights to one end of each string. The weights must be heavy enough to pull the strings tight.



equal length
equal tightness
thick and thin





D. Hang the weighted strings over the edge of a desk or chair so that the strings and weights are not touching anything except where they are attached at the top.

E. *Pluck* each string gently.

9–7. What condition did you change this time and which one(s) did you keep the same?
9-7. Thickness changed; length and tightness remained the same.

9–8. How did the sound of the note change as string thickness increased? 9-8. As thickness increased, the note became lower.

Vibration frequencies of strings are inversely proportional to their lengths, their diameters, and the square roots of their densities, and directly proportional to the square roots of their tensions.

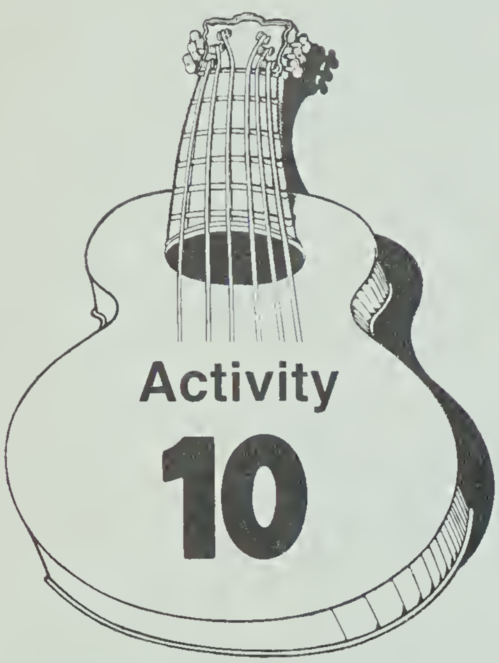
Experiment with different strings on your instrument. Is the lowest note made by the thickest string and the highest note by the thinnest string? Probably so, but you can't be sure this is due to thickness rather than tightness. Careful experiments do show, however, that when length and tightness are kept the same, thick strings produce lower notes than thin strings.

Most stringed instruments produce a wide variety of notes. Choose an instrument such as a guitar, violin, or banjo, that you can inspect either at home or at school. Or you might work with a friend who plays the instrument.

✔ 9–9. What stringed instrument did you inspect?
9-9. Answers will vary.

★ **9–10. What three factors affect the notes played on a stringed instrument?** 9-10. The length, thickness, and tension of the string.

ACTIVITY EMPHASIS: Students listen to a sound tape and see oscilloscope pictures to investigate the effect of overtones on the sound of notes of the same frequency.



To Each Its Own Sound

Electric guitars and saxophones look and sound different. The same note played on each instrument sounds quite different. Yet both sounds are the same frequency. How can two notes of the same frequency sound so different? To find out, you will need these items:

cassette tape for *Sound of Music, Activity 10*
cassette tape player

MATERIALS PER STUDENT UNIT
cassette tape for *Sounds of Music*
cassette tape player, preferably with headphones

The tape will explain the pictures in Figures 10–1 to 10–6. It will also help you answer the questions. Listen to the tape.

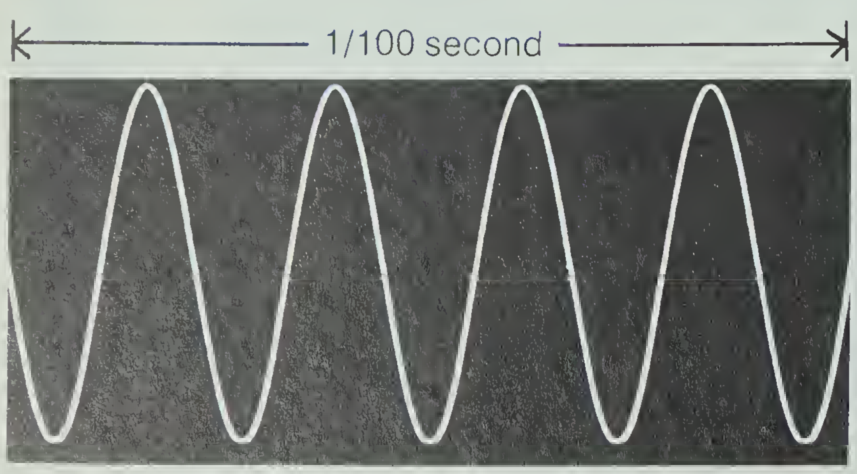


Figure 10–1

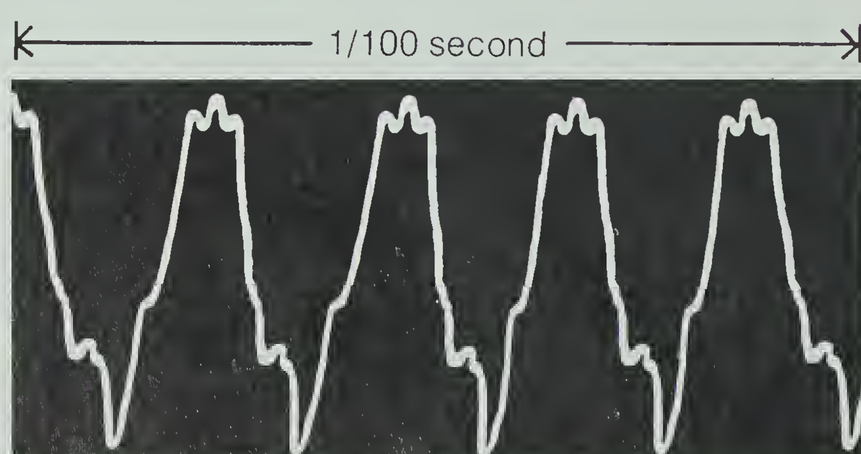


Figure 10–2

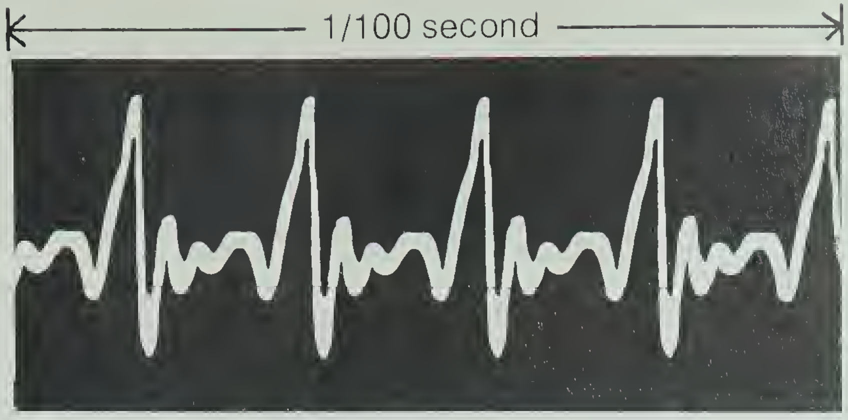


Figure 10–3

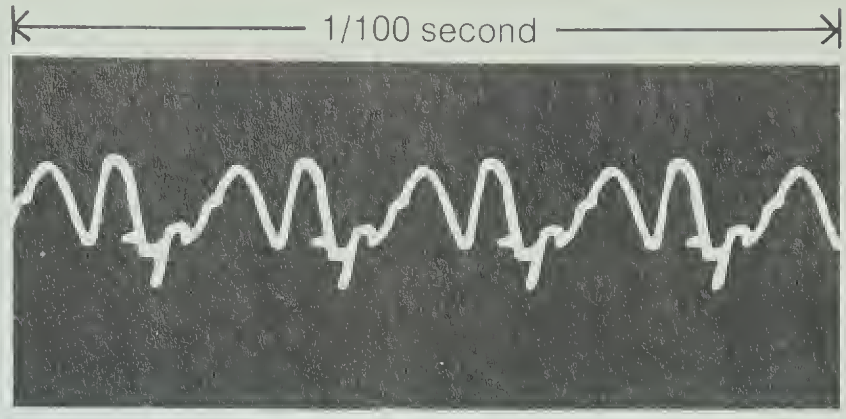


Figure 10–4

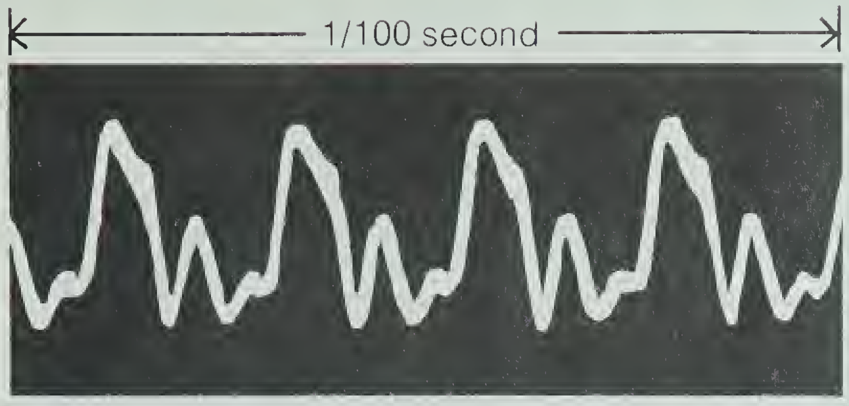


Figure 10–5

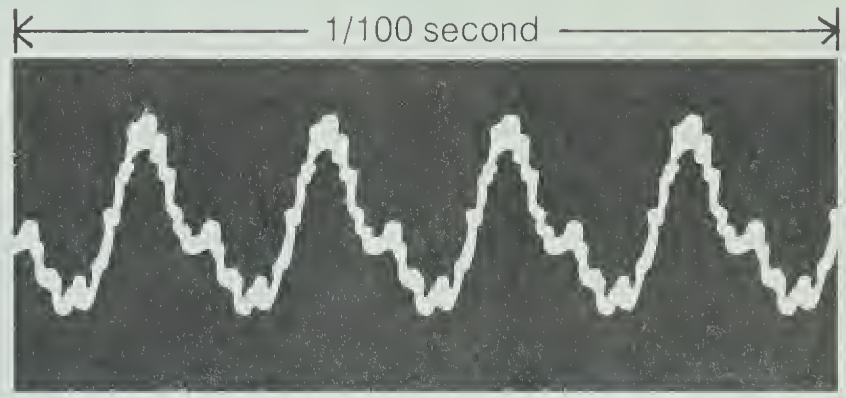
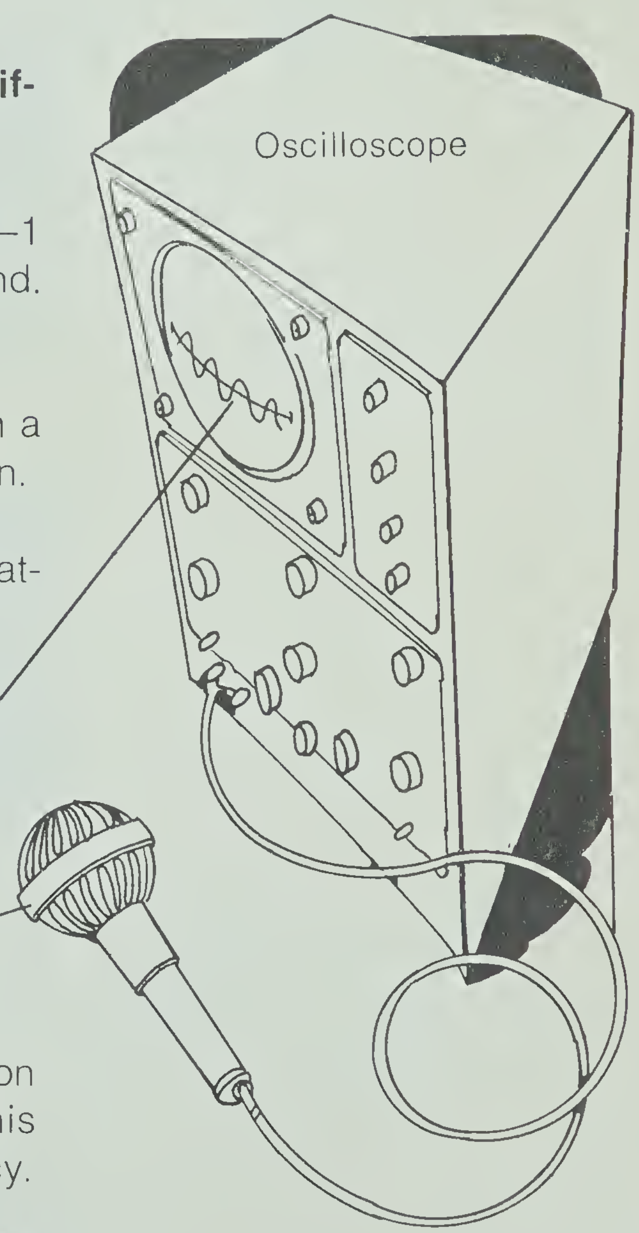


Figure 10–6

★ **10–1. Which instrument does not produce overtones? How can you tell?**
10-1. The tuning fork. There are no wiggles in the wave pattern.

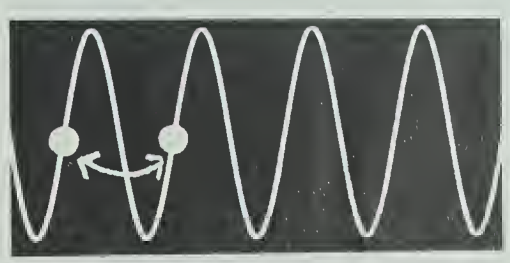
★ **10–2. What causes different instruments to have a different "sound"?** 10-2. Overtones.



The oscilloscope used to make the drawings in Figures 10–1 through 10–6 was set to show the sound made in 1/100 second. Use these drawings to find the frequency of Middle A.

One cycle on the oscilloscope picture is found by going from a certain spot on the repeating pattern to where it begins again.

✔ 10–3. How many cycles do you count in the tuning fork pattern? In each of the other patterns? 10-3. Four and a half.



Example of one Cycle

To find the frequency of Middle A, count the number of cycles on the oscilloscope drawing. Multiply that number by 100. This gives the number of cycles per second, which is its frequency.

Do you see that each drawing has about 4 1/2 cycles? This means there'd be about 100 times as many cycles in a full second, since the picture shows only 1/100 second. So to find the number of cycles in one second, multiply 4 1/2 x 100. That's 450 cycles per second. Actually, the notes are all Middle A—with a frequency of 440 cycles per second. But that's not far off for a rough calculation!

✔ 10–4. What is the frequency of the tone producing Figure 10–7? Figure 10–8? Figure 10–9?

10-4. About 400 cps; about 900 cps; about 1800 cps.

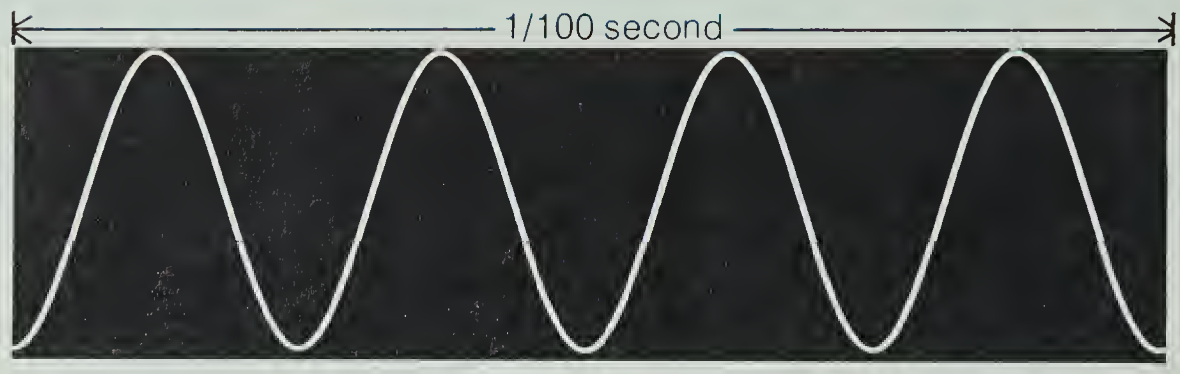


Figure 10–7

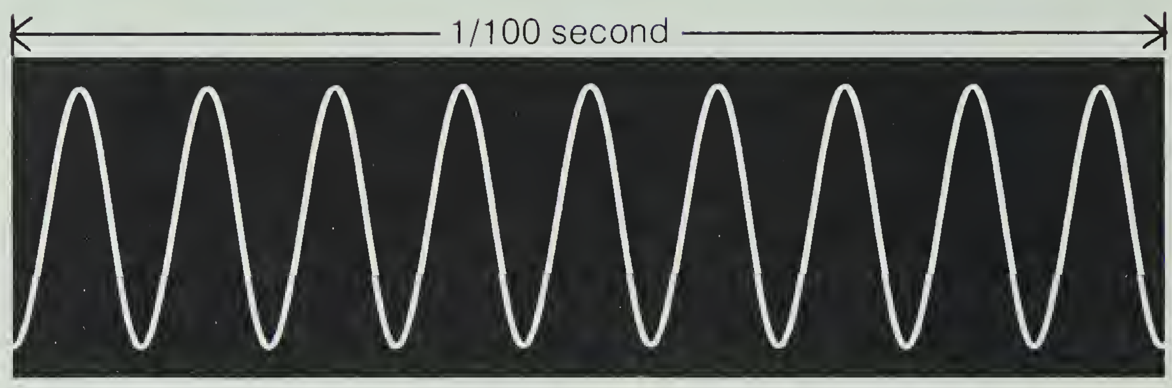


Figure 10–8

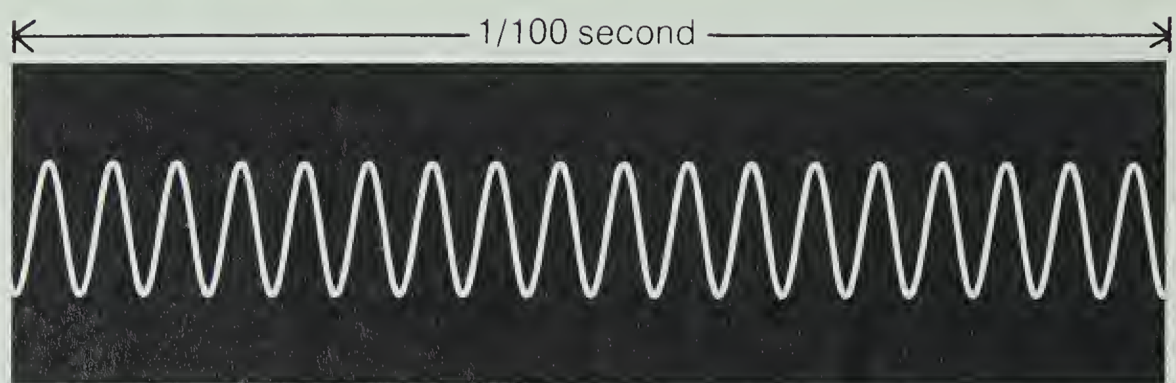


Figure 10–9

The "tallness" of the picture depicts the amplitude of the sine wave. Similarly, the loudness of a sound is a function of the amplitude of the wave motion.

The height of the cycle in the oscilloscope picture is related to the volume of the sound. The louder the sound, the "taller" the picture.

✔ 10–5. What could you say about the loudness of the three sounds pictured in Figures 10–7, 10–8, and 10–9?

10-5. Tone producing Figure 10-7 is the loudest; the tone producing 10-9 is the softest.

ACTIVITY EMPHASIS: A description of suggestions of important things to consider when buying good quality sound equipment.

Buying Sounds

Are you interested in buying equipment to play records or tapes? If not, perhaps you will be in the future. Here are some questions you have to answer *before* you buy: Do you know what to look for in a good sound system? Do you want stereo or quadraphonic? How can you get the best sound for the money you have to spend?

First, you should know what kind of sound you can get from different types of systems. To find out, go to an area where sounds are coming to your ears from all directions.

A. Close your right ear with your finger.

What you hear with the other ear is like listening to the sound that comes from a one-speaker radio or record player. This is called *monophonic* sound.

MATERIALS PER STUDENT UNIT
None.

See Advance Preparation, page TM 5 for some suggestions regarding this activity.

✔ 11–1. With one ear closed, can you tell the direction of the sound? 11-1. Yes.

B. Now cup both hands behind your ears, palms facing forward.

The type of sound you hear is like *stereo* sound. Stereophonic sound has depth to it. Different sounds seem to come from different directions.

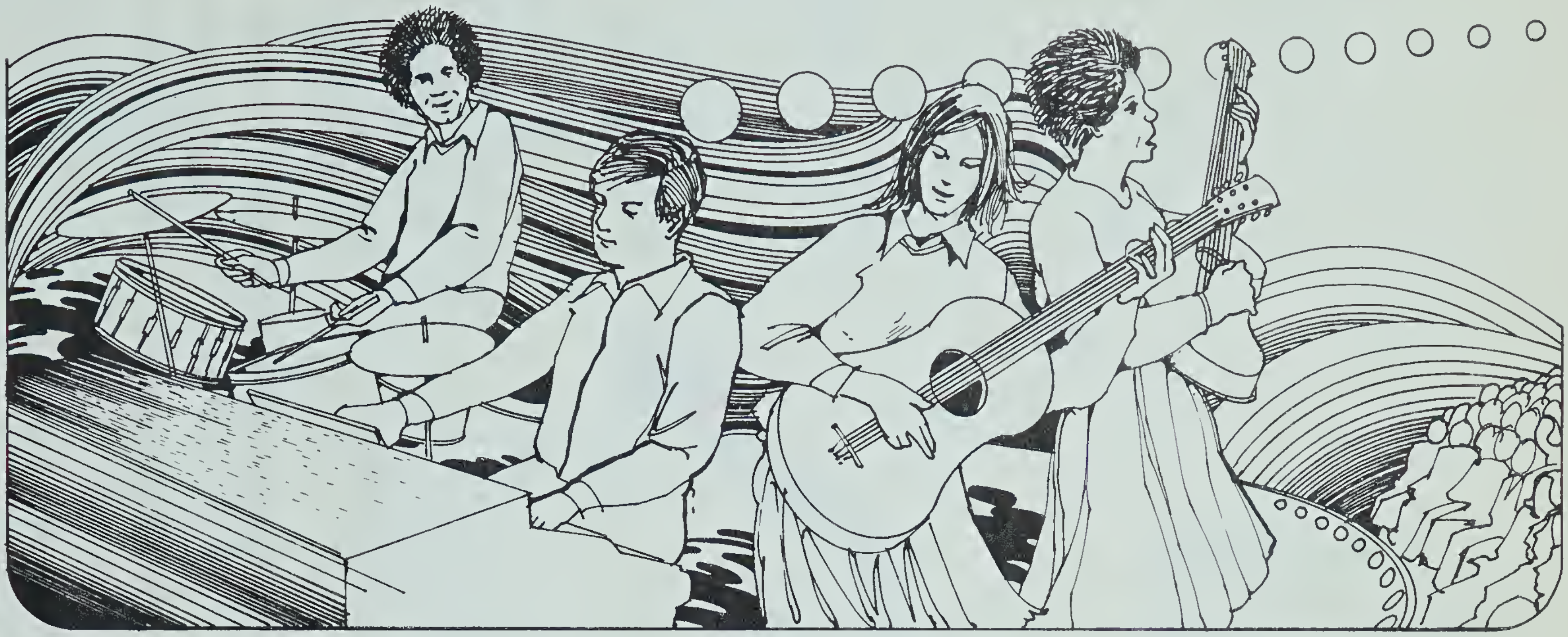
✔ 11–2. Pick out one particular sound. Can you tell what specific direction that sound is coming from? 11-2. Yes. Sound comes from the front of the speaker, either on the left or right side.

C. Take your cupped hands away from your ears.

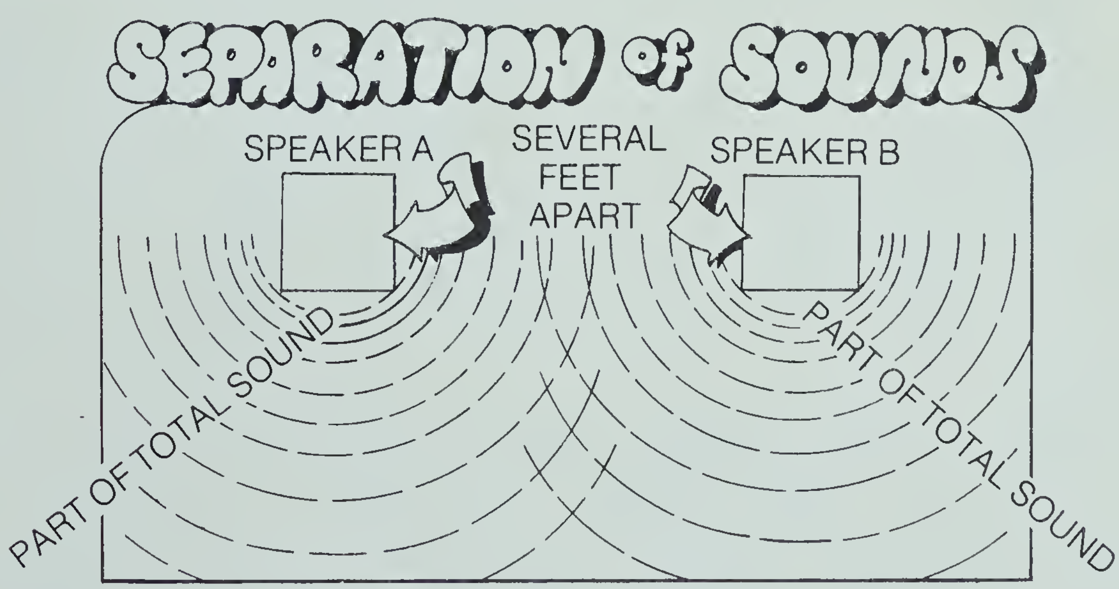
The sound you hear is like *quadraphonic* (quad-ra-FON-ik) sound. Quadraphonic sound is like natural sound. It gives you a sense of sound coming from all directions.

✔ 11–3. Can you tell the direction of a particular sound coming from either in front or in back of you? 11-3. Yes.

Stereo sets produce sound as if the sound were coming from a concert stage—electric piano in the center, drums on the left, and guitars on the right. All seem to be in front of you.



The two speakers of the stereo should be placed several feet apart to help you hear the sound from different directions. Some of the sounds are played through the left speaker and some through the right speaker. You can hear different instruments or singers from different speakers. This separation of sound produces the stereo effect you hear.



✔ 11–4. Where would be the best place to sit if you wanted to get the best stereo effect? 11-4. In the middle between the two speakers.

✔ 11–5. Can you get a stereo sound from one speaker?
11-5. No, the sounds cannot be separated.

The quadraphonic sound systems produce what is sometimes called a quad or a four-channel sound. Four speakers are used.

Figure 11–1 shows how quadraphonic sound speakers are usually placed in a room.

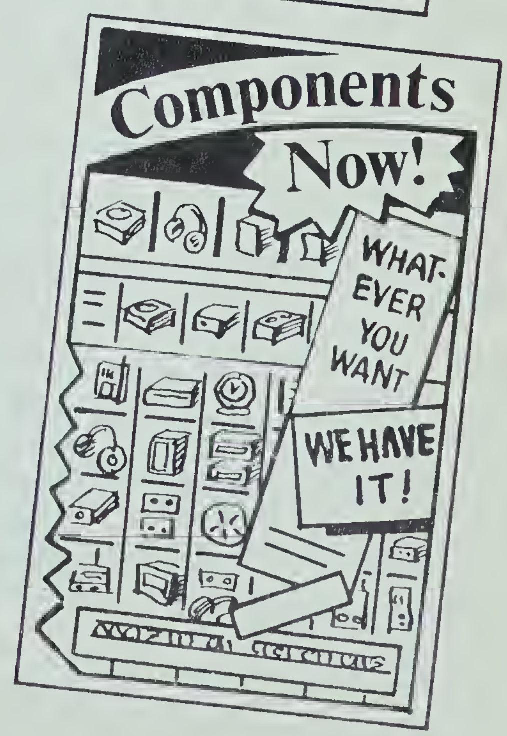
Figure 11–1

✔ 11–6. Why is quadraphonic sound like being in a circle of sound? 11-6. The sounds come from all around you.

11–7. Now you know about the different types of sound systems. If you were buying a record or tape player, what type system would you be satisfied with? 11-7. Answers will vary.


Ready to buy? Not quite. Each kind of sound system can cost anywhere from less than $100 up to several thousands of dollars. How do you know which one is best for you? The least expensive? Maybe. If you have a limited amount of money to spend. The most expensive? Maybe. Although the most expensive isn't always the best, just as the least expensive isn't always the worst.

Take a look at these two ads for sound systems. How would you go about deciding which kind is best for you?



11–8. Make a list of the things you think are important to consider when buying a sound-reproduction system.
11-8. Answers will vary.

Now compare your ideas with the suggestions that follow. You may have thought of some things that were overlooked in this minicourse.

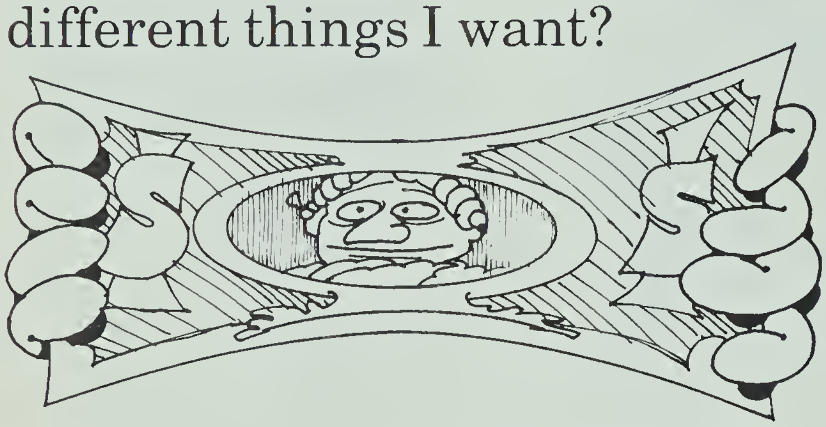
11-9. There are so many different kinds to choose from that it takes an expert to know which is the best buy.

BUYING SUGGESTIONS

11-10. The amplifier is not able to amplify all the sounds that the speaker is able to produce.

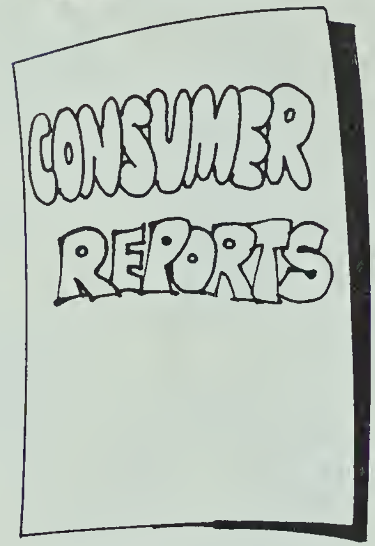
1 Before buying anything, answer these questions for yourself:

1. How will I use the sound system? Will I listen alone? Can I play it loud? Will people usually be talking while the system is playing?
2. How much money can I afford to spend? Can I afford to get what I really want or will I have to make choices among the different things I want?



3. What, if any, special features do I think are important? (Examples of special features: automatic shut-off, jack for earphones.)

2 Try to get a copy of the most recent Consumer Reports Buying Guide.



This guide, published by the Consumer's Union, is loaded with advice, reports on various products, and ratings of different brands or manufacturers.

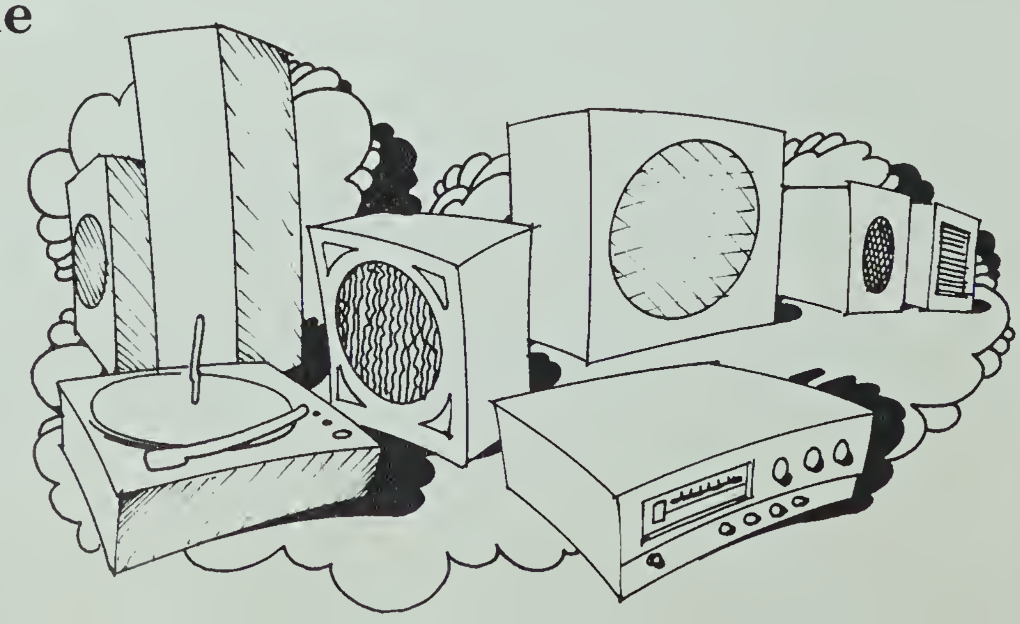
The *Buying Guide* and the monthly *Consumer Reports* magazine are available by subscription or at most book and magazine stores. Back issues might also be available in your school and public libraries.

Consumer's Union also publishes special issues which describe and rate only sound systems.

★ 11-9. Why is it a good idea to have information and expert opinions on any sound system you're thinking about buying?

3 Know what each part of the sound system does.

✔ 11-10. Why would it be a waste of money to buy very good quality speakers to use with an amplifier which cannot amplify all sounds?



1-11. You may wish to return the sound system; you may need to have it repaired; you may want to review the operating instructions.

FOR SOUND SYSTEMS

1-12. Answers will vary.

4 Check equipment for these sound-reproduction problems.

1. *Poor frequency response.* The system cannot reproduce all of the notes from the lowest to the highest evenly.

2. *Distortion.* The sound reproduced by the system is harsh and gets worse as you turn the volume up.

3. *Rumble.* A vibration within the system itself is being amplified.

4. *Flutter.* The pitch wavers, or flutters, because the turntable or tape drive is not moving at a steady speed.

5. *Hiss or hum.* Something in the system is producing an unwanted noise.

5 Have the sales-person show you how to use the equipment. Then look it over and try it out yourself. Compare two systems by playing them in as similar conditions as possible. The best possible place to try them out would be in the room where you plan to put it.

Is the equipment easy to operate? Are the controls handy? Are there any noticeable sound problems? Does it have the features you want?

6 Compare different models. The model which can give you the most of what you want for the least amount of money is the best buy.

7 After buying a sound system, keep the guarantee and all purchase receipts and instructions together in a safe place.

✔ 11–11. What are some reasons for Suggestion 7?

✔ 11–12. Which of these suggestions should you add to your original list?

advanced

Planning 12 Activity

Activity 13 Page 54

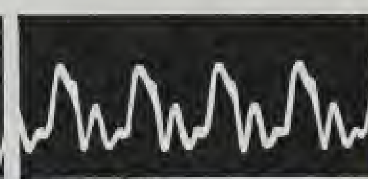
Objective 14: Describe the mathematical relationship between the velocity, the frequency, and the wavelength of a sound wave.

Sample Question: What is the formula for finding the velocity of sound in metres per second? (v=velocity, λ= wavelength, f=frequency)

Activity 14 Page 58

Objective 15: Use a wave model to explain the difference in pitch, loudness, and quality of different sounds.

Sound A



Sound B

Sample Question: These pictures were made with the oscilloscope on the same settings. Which of the following statements is true about these two sounds?

a. Sound A is higher pitched than Sound B.
b. Both sounds have the same frequency.
c. Both sounds were made by the same instrument.
d. Sound A is louder than Sound B.

CH A

VARIABLE VOLTS/CM

POSITION

Objective 16: Describe how the loudness and energy of a sound wave are related to the distance from the source of the sound?

Sample question: If a bell rings in a steeple in the middle of town, it will not sound as loud to people at the edge of town as it does to people in the center of town. Why?

a. The sound wave gets shorter as it moves away from the source.
b. The energy of the original sound wave has been spread out over more air space.
c. The frequency of the sound wave has been reduced.
d. The energy of the original sound wave has been increased by the air.

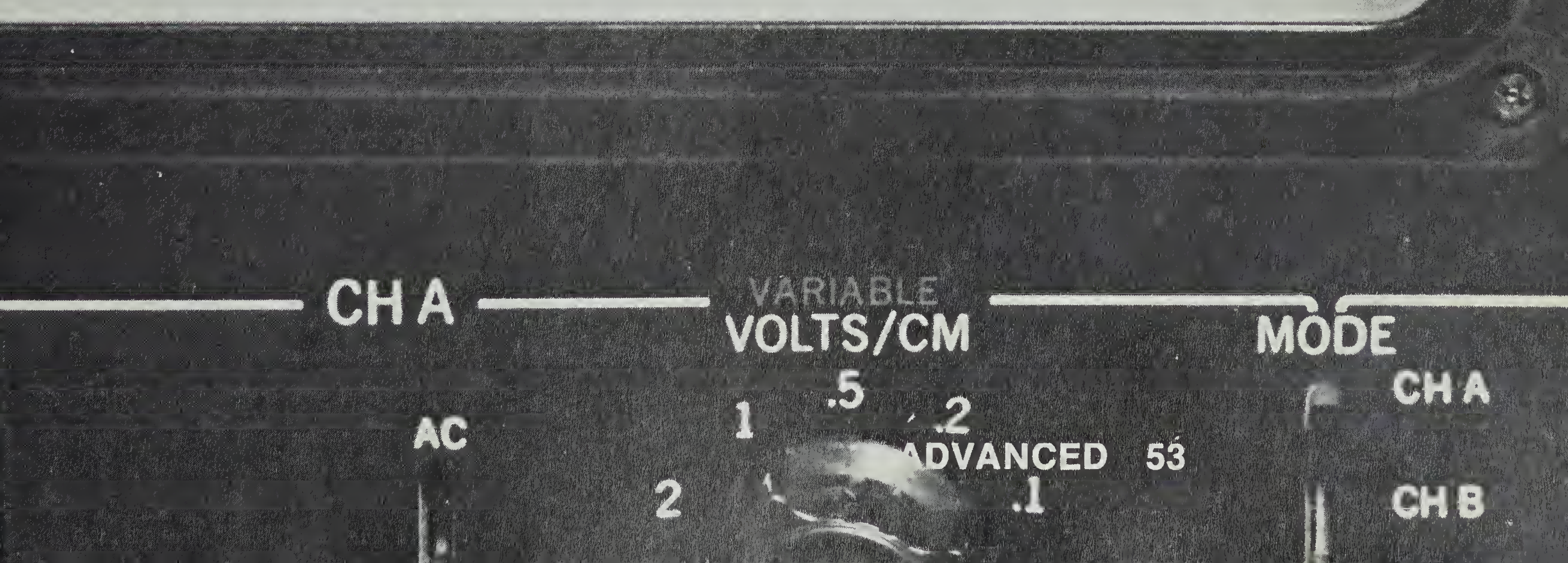
Activity 15 Page 64

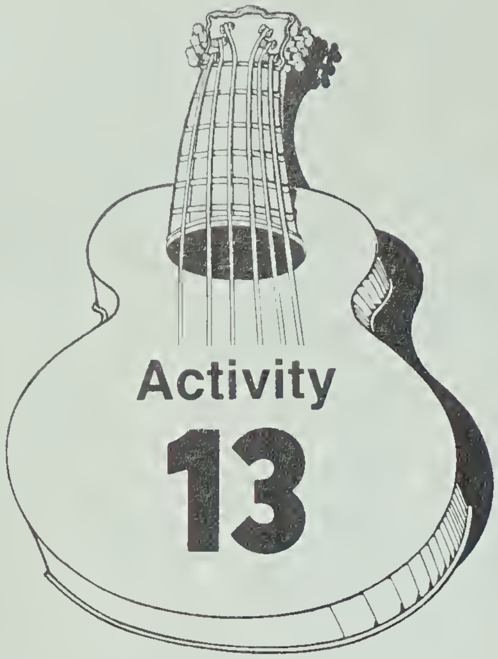
Objective 17: Describe how the notes of octaves, scales, and major chords are mathematically and musically related.

Sample Question: How far apart are two notes if one has twice the frequency as the other note?

Answers

14. $v=\lambda f$ 15. *d* 16. *b* 17. *an octave apart*





ACTIVITY EMPHASIS: Students use the relationship $v = f\lambda$ and the values of two of the variables to calculate the third.

Moving Sound

MATERIALS PER STUDENT UNIT

None.

In the lawless days of the Old West, train robbers were said to have put their ears on the steel tracks to listen for approaching trains. Folklore also says that the American Indian buffalo hunters would put their ear to the ground to listen for buffalo hoofbeats.

✔ 13–1. What do these stories suggest about how sound travels in steel and in soil as compared to air?

13-1. Sound travels better in steel and soil than in air.

Sound travels through different substances at different speeds, or *velocities*. Sound travels slowest through air. Air is a poor conductor of sound. Water is better than air. But solids such as steel and glass are the best. Not only does sound travel faster through a steel rail, for instance, but it travels farther before dying out.

The velocity of sound also depends on temperature. In air, the velocity increases by 0.6 metre per second for each Celsius degree increase in temperature.

Figure 13–1 shows the velocities of sound through some common substances.

VELOCITY OF SOUND IN VARIOUS SUBSTANCES

Substance	**Velocity** in metres per second (m/sec)
Air	330
Water	1500
Copper	3550
Wood	4000
Steel	5000
Iron	5000
Aluminum	5140
Glass	5500
Granite rock	6000

Figure 13–1

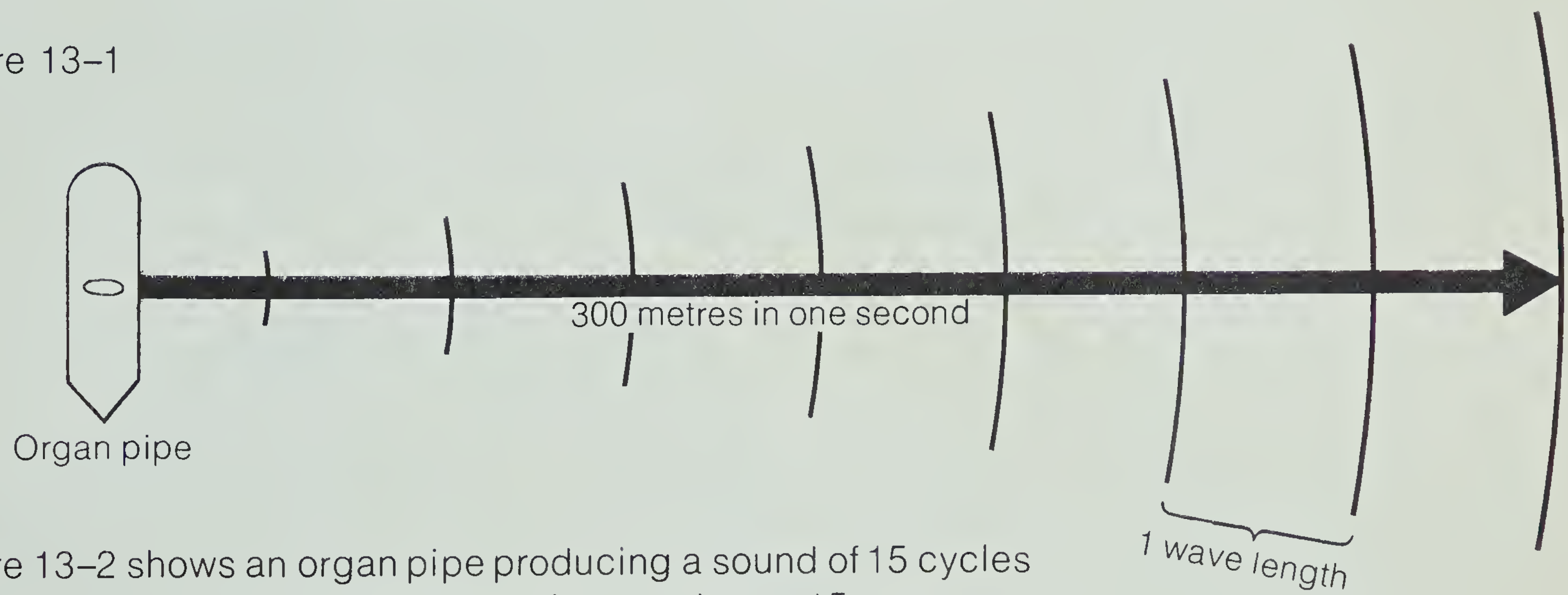


Figure 13–2

Figure 13–2 shows an organ pipe producing a sound of 15 cycles per second. In one second, the pipe produces 15 compressions. The sound is traveling at a velocity of 300 metres per second according to Figure 13–2. This means that the 15 compressions are spread over 300 metres. The distance between two successive compressions is the length of one sound wave. The length of a wave is called the *wavelength* of the sound.

What is the wavelength of the sound produced by the organ pipe? Remember that there are 15 compressions in one second. This means that one wavelength is 1/15 of the 300 metres the wave travels in one second. Thus,

$$\text{Wavelength} = 1/15 \times 300 \text{ metres} = 20 \text{ metres}$$

The wavelength of any sound is the length of one wave, no matter what the frequency is. Suppose you have a sound with a frequency of 100 cycles per second and velocity of 300 metres per second. This means that 100 cycles, or compressions, are spread out over 300 metres. What is the wavelength of the sound? One wave is 1/100 of the 300 metres the wave travels in a second.

$$\text{Wavelength} = 1/100 \times 300 \text{ metres} = 3 \text{ metres}$$

Symbols are used to make things simpler. The Greek letter λ (lambda) is used for wavelength, and f is used for frequency.

Wavelength (λ) is measured by metres per wave.

$$\frac{\text{metres}}{\text{wave}}$$

Frequency (f) is measured in waves per second.

$$\frac{\text{wave}}{\text{second}}$$

Metres per wave (λ) multiplied by waves per second (f) equals metres per second.

$$\frac{\text{metres}}{\text{wave}} \times \frac{\text{waves}}{\text{second}} = \frac{\text{metres}}{\text{second}}$$

Since the velocity of sound is constant for a given medium at a given temperature, $f\lambda$ = constant, and thus frequency and wavelength are inversely proportional to each other.

When you multiply λ and f together you get metres per second. Metres per second is a measure of velocity (v), like miles per hour. So velocity of sound can be calculated by multiplying wavelength times frequency.

$$\text{velocity} = \text{wavelength} \times \text{frequency}$$

$$v = \lambda \times f$$

$$v = \lambda f$$

This relationship is true for any wave motion. If you know any two pieces of information, you can find the third. For instance, if you know the velocity and frequency of a sound, you can find its wavelength.

Example: Find the wavelength of a sound wave from a 440-cycle-per-second tuning fork. (The sound is Middle A.) The velocity is 330 metres per second, the velocity of sound in air.

$$v = f\lambda$$

$$330 = 440 \times \lambda$$

$$\frac{330}{440} = \lambda$$

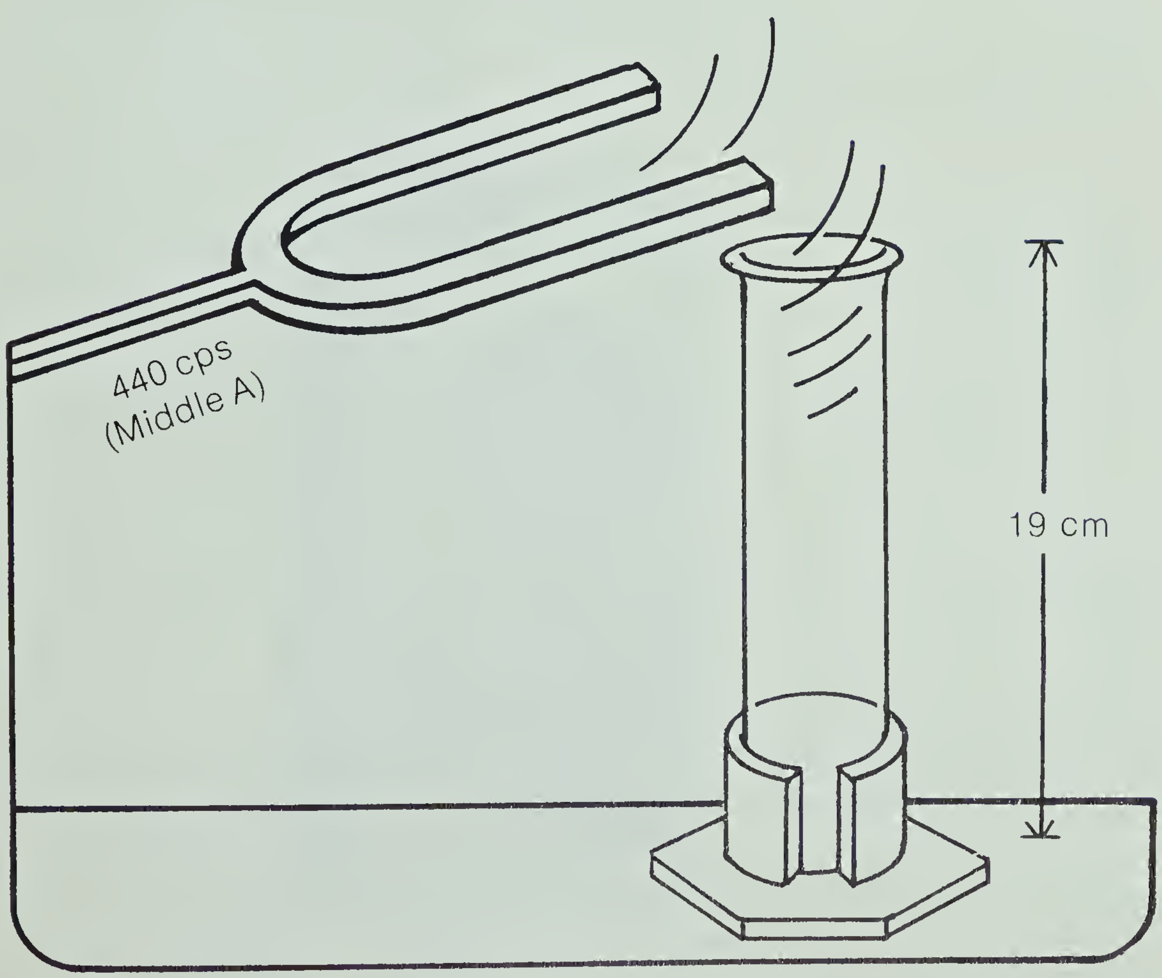
$$\lambda = 0.75 \text{ metre}$$

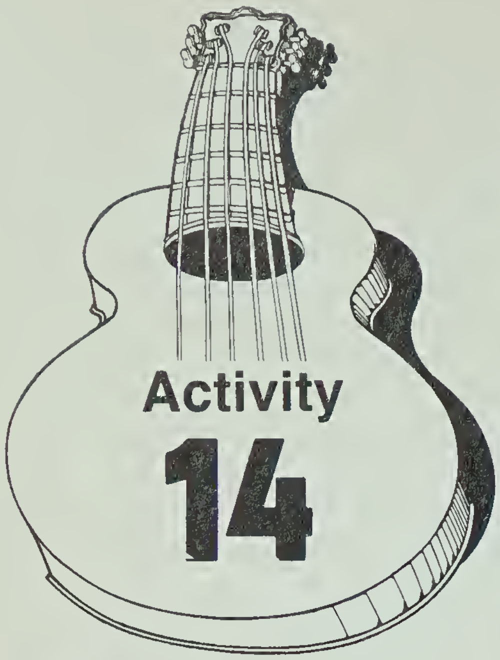
✓ 13–2. The velocity of sound in water is about 1500 metres per second. What is the wavelength of a 440-cycle-per-second sound wave traveling through water? 13-2. 3.41 metres

★ **13–3. A cylinder will begin to vibrate when the length of its air column is one-fourth the wavelength of the sound entering it. In an experiment a cylinder, 19 cm high, vibrates to a tuning fork of a frequency of 440 cycles per second. Use this data to calculate the following:** 13-3. (a) 0.76 m (76 cm) (b) 334.4 m/sec (33,440 cm/sec)

a. Wavelength of the 440-cycle sound

b. Velocity of the 440-cycle sound

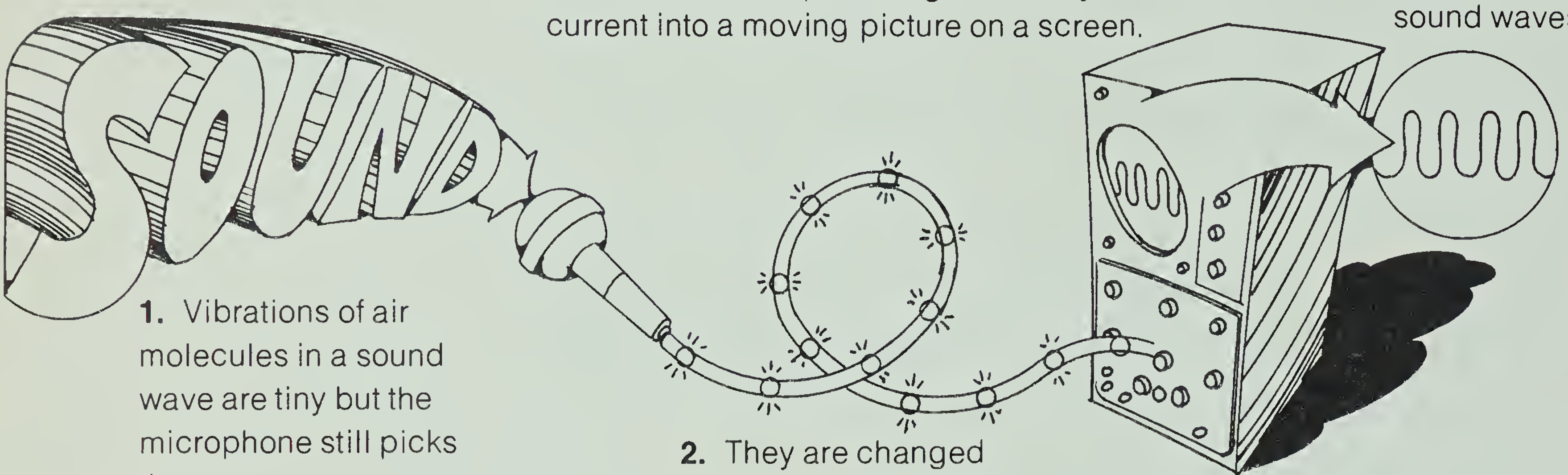




ACTIVITY EMPHASIS: Students use either an actual oscilloscope or oscilloscope pictures in the student booklet to observe that different kinds of sounds produce different wave patterns.

Seeing Sounds

Our eyes can't *see* sound waves. Our ears hear sounds. But sometimes it would be helpful to be able to see, as well as hear. It isn't possible to make the actual sound waves visible. But an electronic instrument called an *oscilloscope* can produce pictures which show us what sound waves are *like*, even if it can't show the sound wave itself.



MATERIALS PER STUDENT UNIT
oscilloscope (optional)
microphone (optional)
tuning fork (optional)
rubber striker (optional)

See Advance Preparation, page TM 6, for notes on using the oscilloscope in this activity. Further help is provided under Background Information, page TM 7.

If an oscilloscope is set up in your classroom, use it to see for yourself much of what is covered in this activity. If you do not have an oscilloscope, pictures are provided in this book for you to use with this activity.

ONE TYPE OF OSCILLOSCOPE

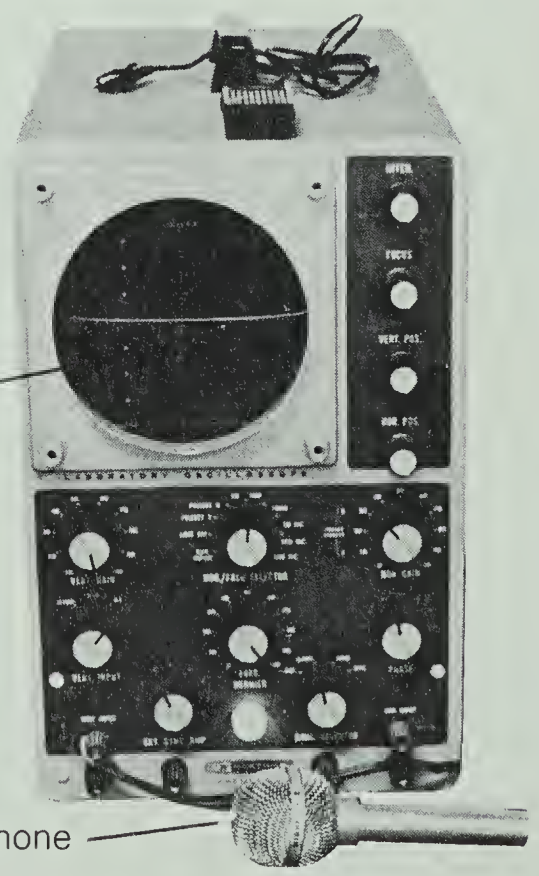


Figure 14–1 shows how sound waves finally wind up as a picture on the screen of an oscilloscope.

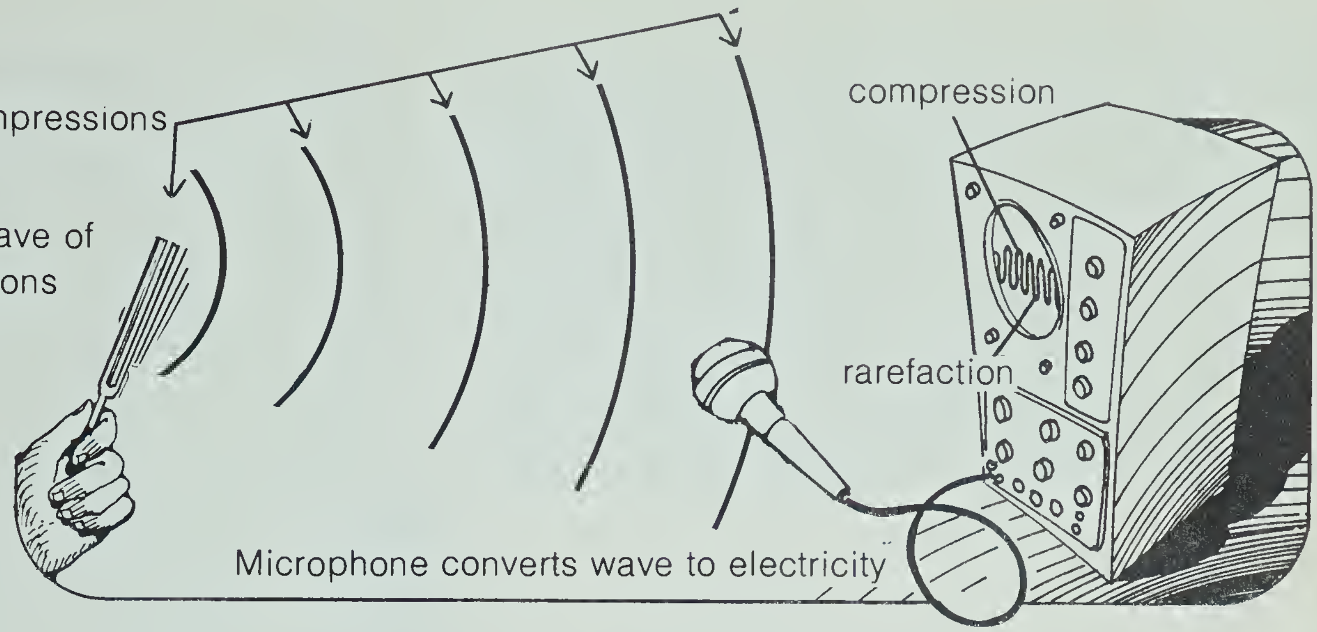


Figure 14–1

After the sound waves enter the microphone, they're pictured on the screen. The peaks at the top of the screen are compression bands. The valleys at the bottom correspond to the spread-out areas, or rarefactions, between the compressions.

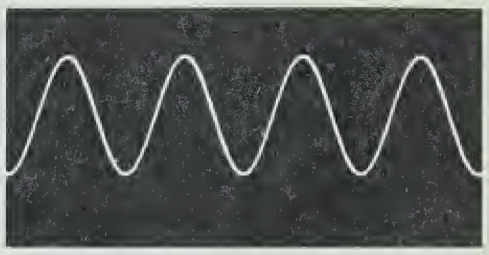
How does the sound wave pattern of a high-pitched note differ from that of a low-pitched note?

How is the sound wave for a soft sound different from the sound wave of a louder sound? What's different about the sound waves of two notes from different sources?

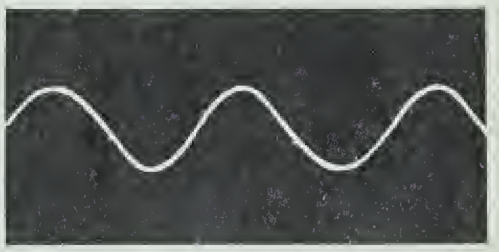
You can use oscilloscope pictures of sounds to investigate these questions. Use either your own drawings of oscilloscope patterns or the ones provided in this activity.

Figure 14–2 shows the oscilloscope pattern for a Middle-A and then a Middle-C tuning fork. Each picture shows the sound wave pattern for the same period of time.

Look carefully at Figure 14–2 and at your own sketches, if you made them. Remember that Middle A is a higher note than Middle C.



1. Middle-A tuning fork



2. Middle-C tuning fork

Figure 14–2

The number of compressions or rarefactions is, of course, a measure of the frequency of the sound wave. The greater the number of compressions in a given period of time, the higher the frequency.

★ **14–1. Does the sound wave for A have more or fewer compressions (high peaks) than the sound wave for C?**
14-1. More compressions.

✔ 14–2. Does the Middle-A tuning fork vibrate faster or slower than the Middle-C fork? 14-2. Vibrates faster.

Pitch is a musical term which describes the effects of the frequency of the sound wave. As the frequency increases, the pitch becomes higher.

The word used to describe whether a musical note is higher or lower is *pitch*. Pitch depends on frequency. The higher the frequency, or number of vibrations per second, the higher the pitch.

14–3. If you hit a piano key near the left end of the keyboard, you hear a low-pitched note. If you hit a key near the right end, you hear a high-pitched note. What's the difference in the sound waves? 14-3. The low-pitched note has a lower frequency; the high-pitched note has a higher frequency.

If you blow a trumpet hard, you hear a loud musical note. If you blow the same note softly, you hear a soft note. What's the difference between these sound waves?

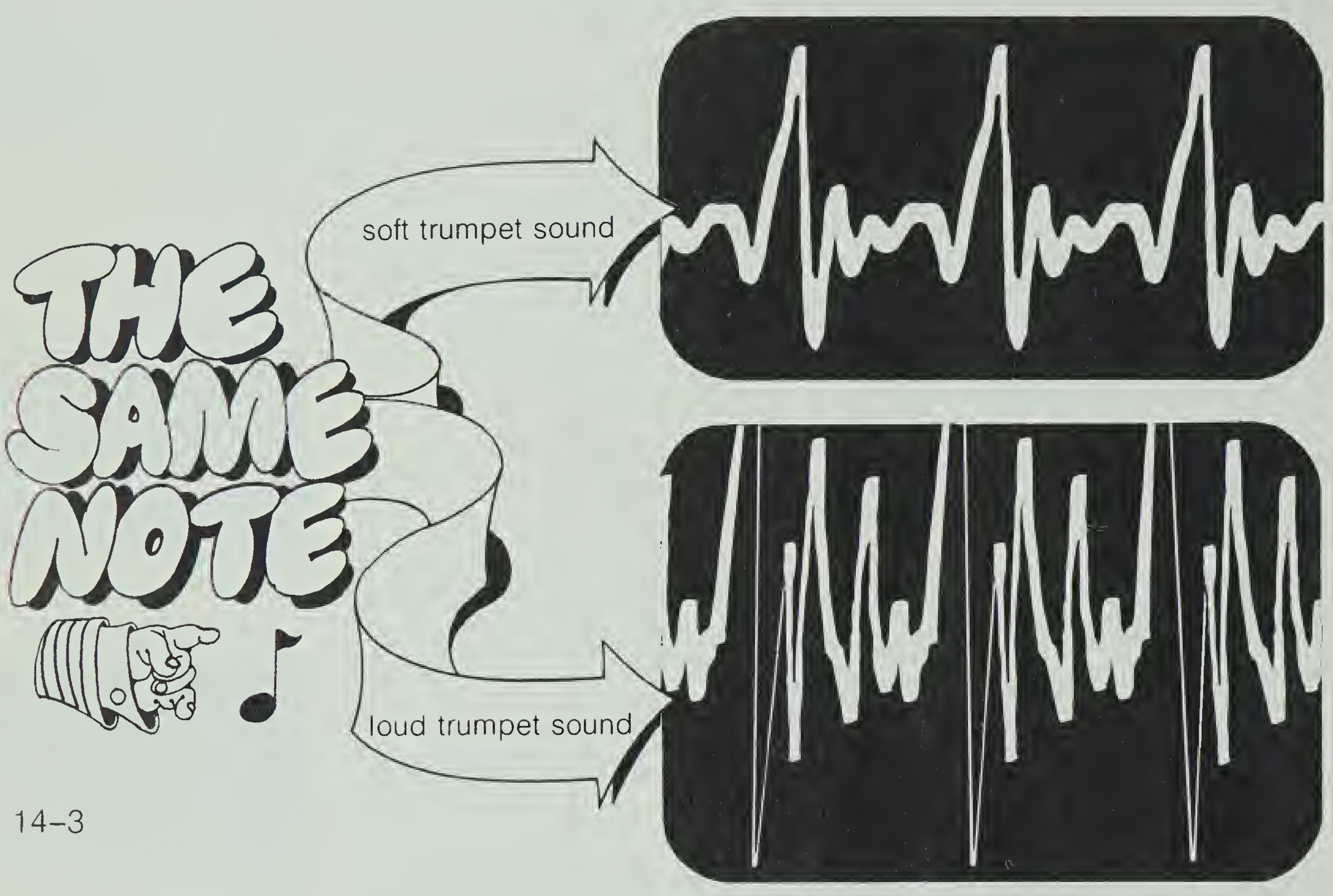


Figure 14–3

Look at the oscilloscope pictures in Figure 14–3.

14–4. Are the wave patterns of the soft and loud notes the same? How can you tell? 14-4. No. The peaks are higher for the loud notes.

Notice that the peaks of the loud note are higher than the peaks of the soft note.

Amplitude is a term which describes the displacement of the particles of the transmitting medium.

The height of a wave is called its *amplitude*. When the peaks are higher in one wave pattern than another, we say the amplitude of the first wave is greater.

Here are two more oscilloscope wave patterns.

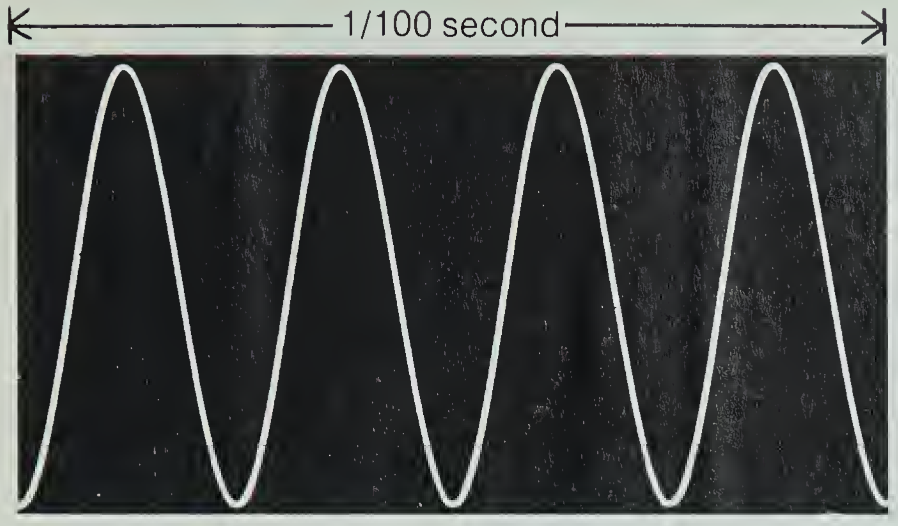


Figure 14–4

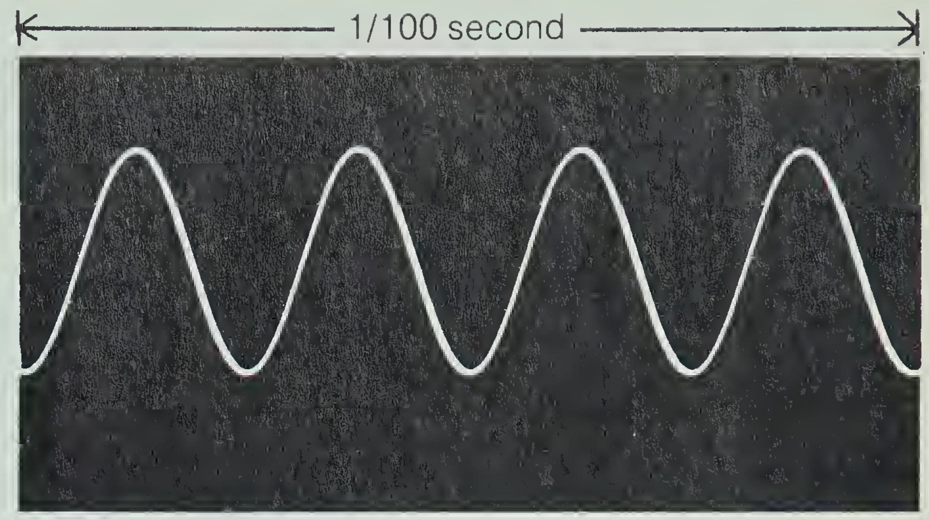


Figure 14–5

14–5 Are the waves in Figures 14–4 and 14–5 of equal amplitude? If not, which has the higher amplitude?

14-5. No. The sounds in Figure 14-4 have higher amplitude.

14–6. Are the sounds in these pictures of equal loudness? If not, which is louder? 14-6. No. The sounds in Figure 14-4 are louder.

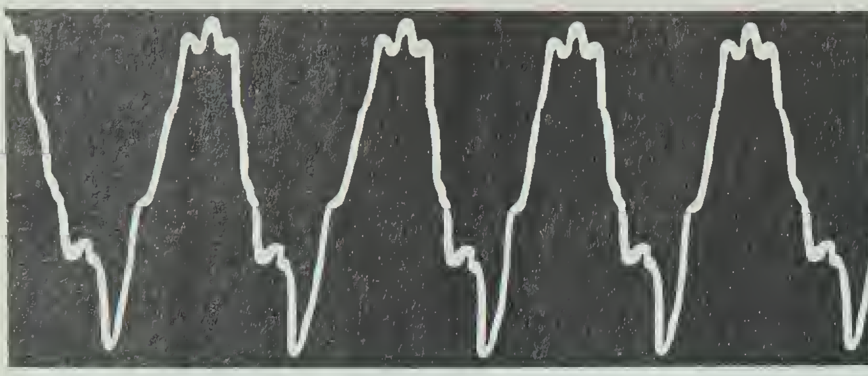
★ **14–7. How is loudness related to amplitude?** 14-7. A loud note will have a larger amplitude than a softer note of the same frequency.

The vibrations of the air column in the trumpet which produced the oscilloscope pictures in Figure 14–3 did not produce "pure" sound waves. Other frequencies in addition to the main one, the tallest peak, were produced at the same time. These other frequencies are called *overtones*, tones in addition to the main or fundamental tone.

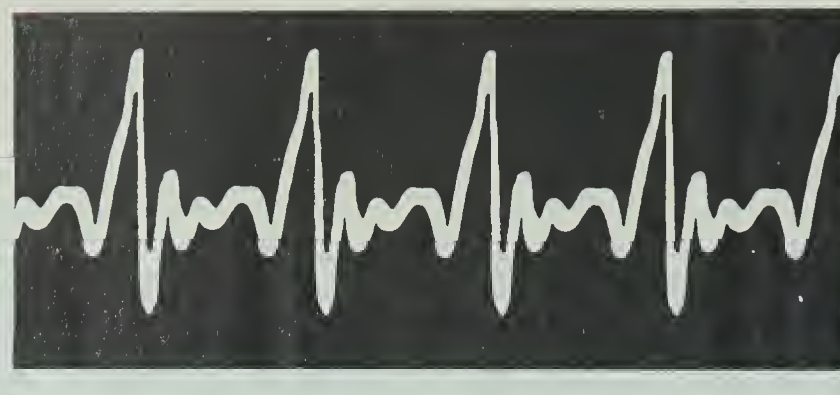
The overtones occur in the same place in every cycle of the repeating pattern.

The amplitude of sound waves in air is generally very small. An amplitude as large as 1/100 cm may result in a sound loud enough to damage the ear.

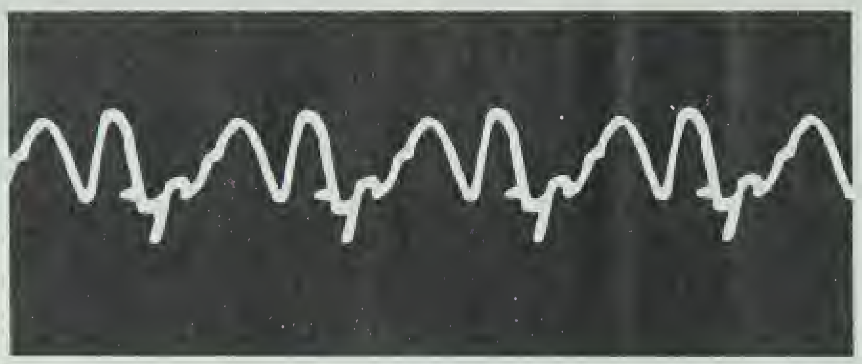
The fundamental tone is also the lowest possible tone that can be produced by the air column under the given conditions. It is a result of the simplest possible vibrational mode — when the air column vibrates as a whole. More complicated vibrations (due to the air column vibrating in parts) produce the higher frequencies of the overtones.



piano



trumpet



saxophone

Figure 14–6. Oscilloscope pictures of the same note played on each instrument.

Figure 14–6

The point at which a string is set in vibration dictates the number of overtones produced. In a piano, for instance, the strings are struck at a point approximately 1/7 of the way from the end.

★ **14–8. What is different about the same notes played on different instruments?** 14-8. There are different overtones for the same notes played on different instruments.

Overtones give richness and "personality" to the notes.

✓ 14–9. In which of the instruments is the fundamental note the most clearly heard? (Hint: Has the weakest overtones.)
14-9. Piano.

✓ 14–10. On which of the instruments is the fundamental note least clearly heard, that is, "colored" by many strong overtones?
14-10. Saxophone.

Look at Figure 14–7. Jim is calling out two friends, Kathy and Flo. One is standing close to him, the other far away.

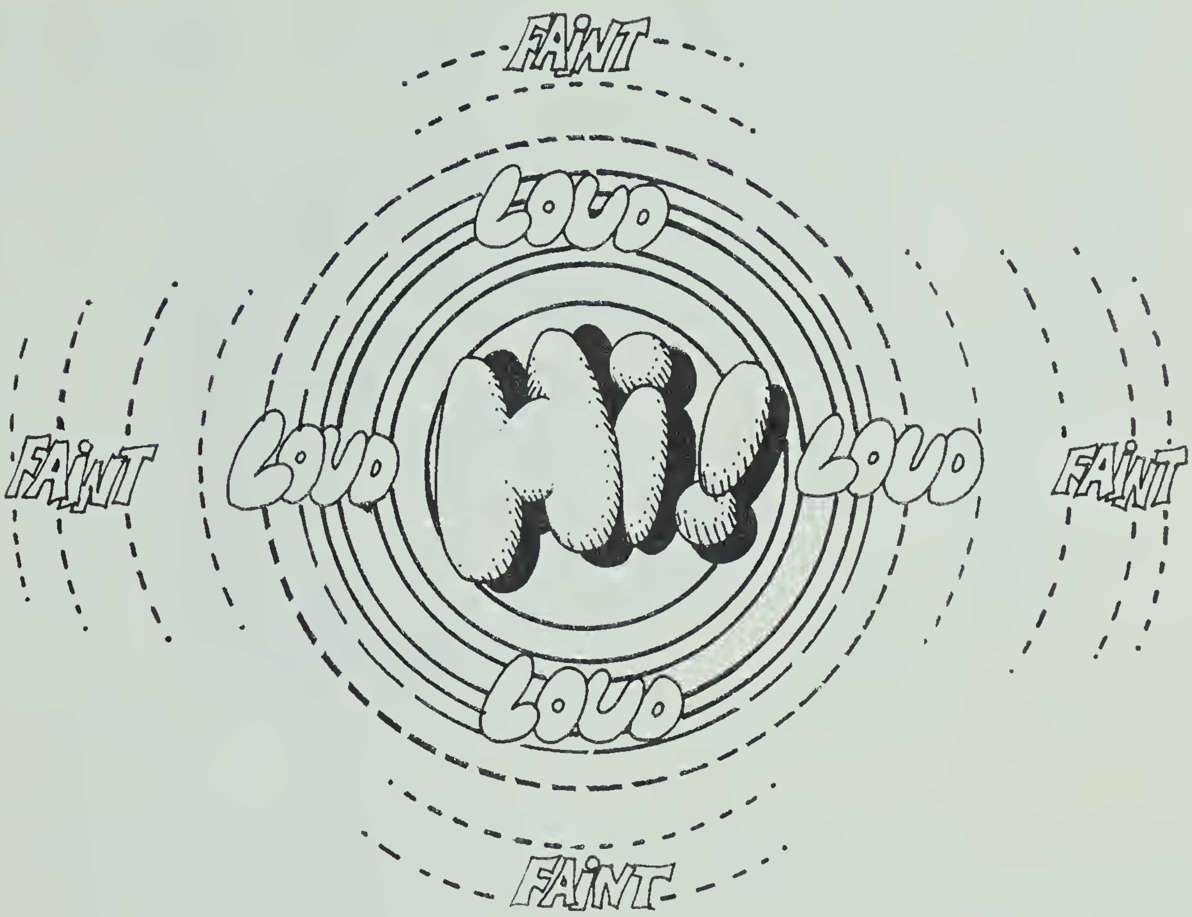
✓ 14–11 Will Jim sound louder to Kathy or to Flo?
14-11. Kathy.

Figure 14–7

The further away you get from something that's making noise, the less you hear. Why is that? Review two basic ideas about sound:

1. Sounds are produced by vibrations.
2. Sound travels out in all directions as a disturbance in the air, or whatever substance it's travelling through.

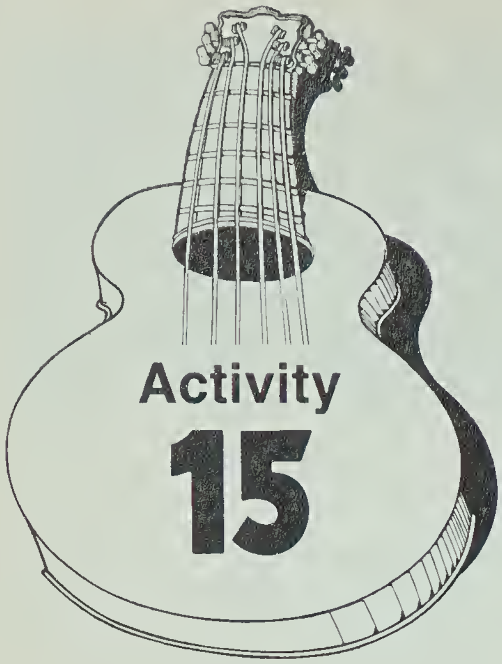
Suppose Jim yelled "Hi" to the two girls. It took a certain amount of energy to make the sound of "Hi."



The energy needed to yell "Hi!" made molecules in the air move faster. That disturbance kept moving through more and more air. The amount of energy left over to move air far away from the source is very small. Therefore, the "Hi" sounds are very faint. Close to the source, the "Hi" sounds much louder. This is because the full force of the compression disturbance is felt.

As it moves from the source, the sound eventually dies away completely. This is caused by two factors. Some of the disturbance energy is converted to heat every time air molecules are moved. But more important, as the disturbance wave spreads, the wave energy at any point on the wave is less and less.

★ **14–12. Explain why the loudness of a sound decreases as it moves farther from the source.** 14-12. The sound wave [illegible] spread out and some of the sound energy gets changed to heat.



MATERIALS PER STUDENT UNIT

cassette tape for *Sounds of Music*

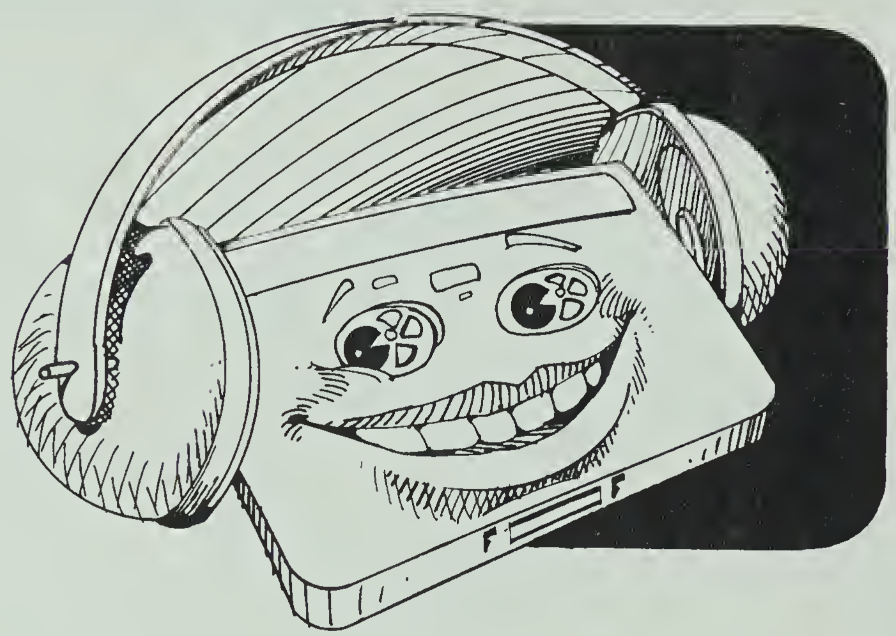
cassette tape player, preferably with headphones

ACTIVITY EMPHASIS: The relationship between notes within an octave, how notes are arranged in scales, and how notes are arranged in major cords.

Octaves, Scales and Harmony

Music is a special collection of sounds that can move you to great feeling. This activity is about the structure of music—how notes are arranged to produce different feelings. To help you hear what the words and pictures in this activity are about, you will need these items:

tape cassette for *Sounds of Music, Activity 15*
tape cassette player



You can listen to the entire tape before answering any of the questions. Or you can go back and forth, reading and listening to each part. Either way, start by listening to the tape now. You will also need to look at Figure 15–1, which shows part of a piano keyboard with the keys labeled by name and by frequency.

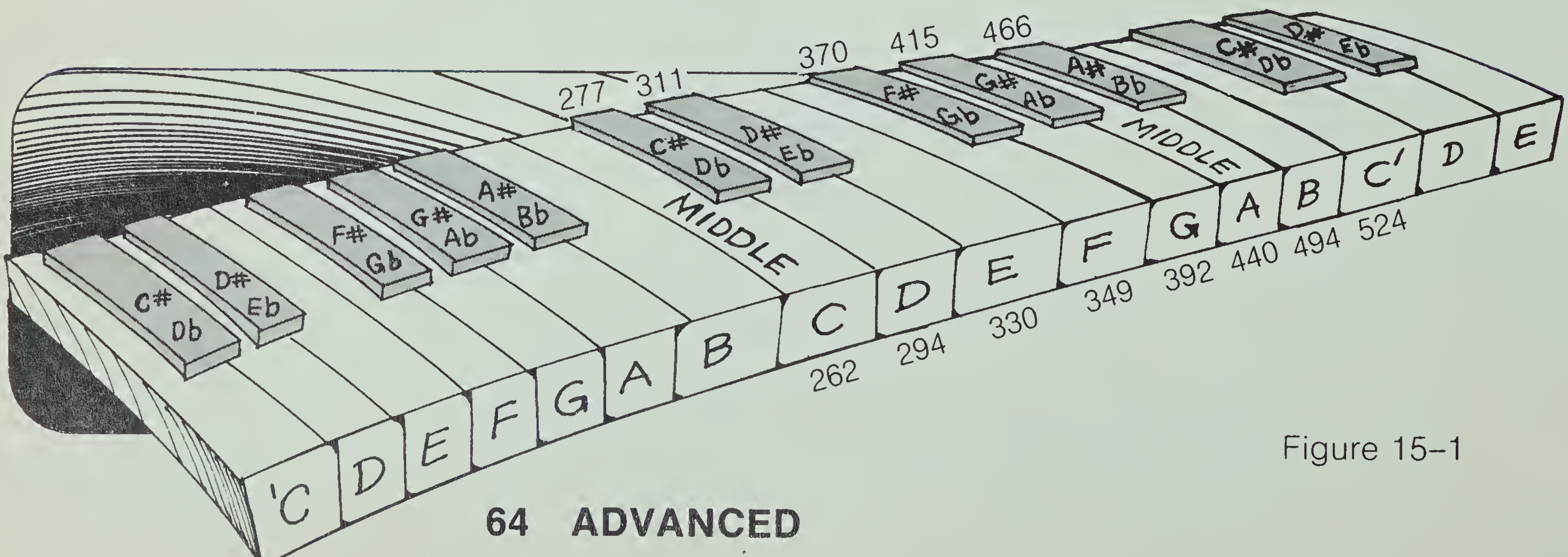


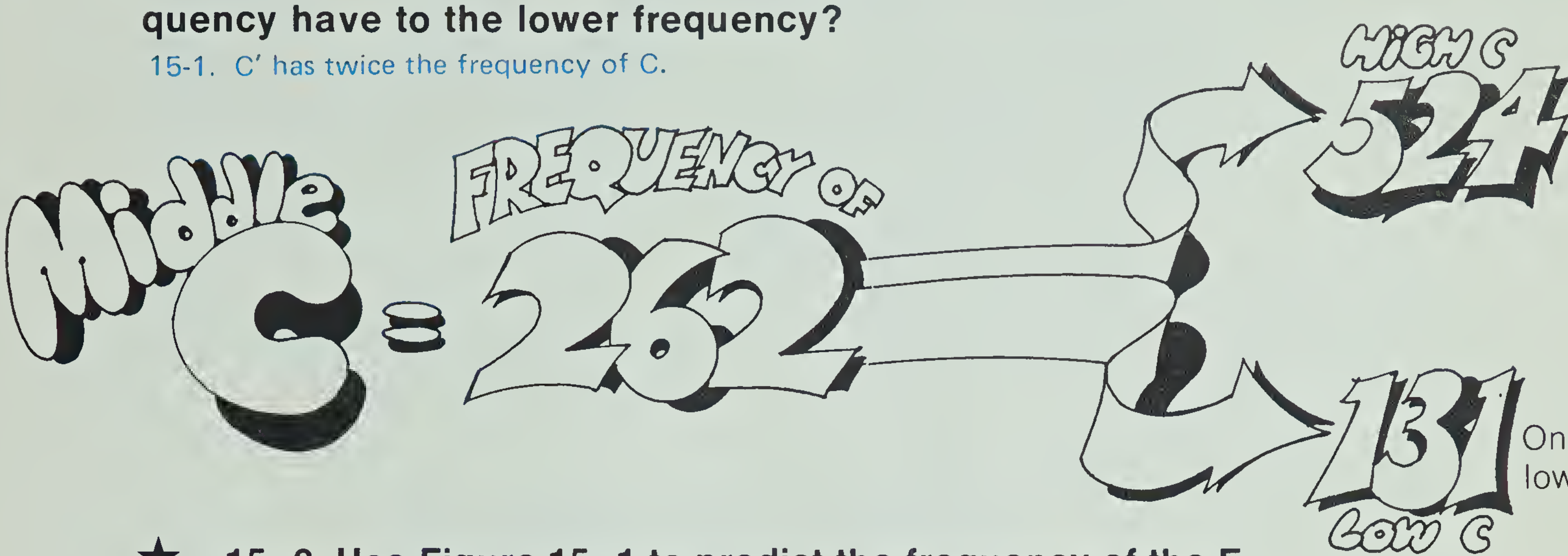
Figure 15–1

OCTAVES

There is a relationship between notes one octave apart. This relationship has to do with the frequency of the notes.

★ 15–1. Look at the frequencies of the two notes C and C', one octave apart. What relationship does the higher frequency have to the lower frequency?

15-1. C' has twice the frequency of C.



★ 15–2. Use Figure 15–1 to predict the frequency of the E that falls
a. one octave lower than the E listed.
b. two octaves higher than the E listed.

15-2. a. 165 cps
b. 1320 cps

Half steps are shown in Figure 15–2. A half step is the distance from C to C# (read as "C sharp"), C# to D, and so on.

15–3. What note is a half-step higher than G#?

15-3. A.

15–4. What note is a half-step lower than C?

15-4. B.

In Figure 15–2, C to D, and E^b to F, are among the pairs that are a whole step apart.

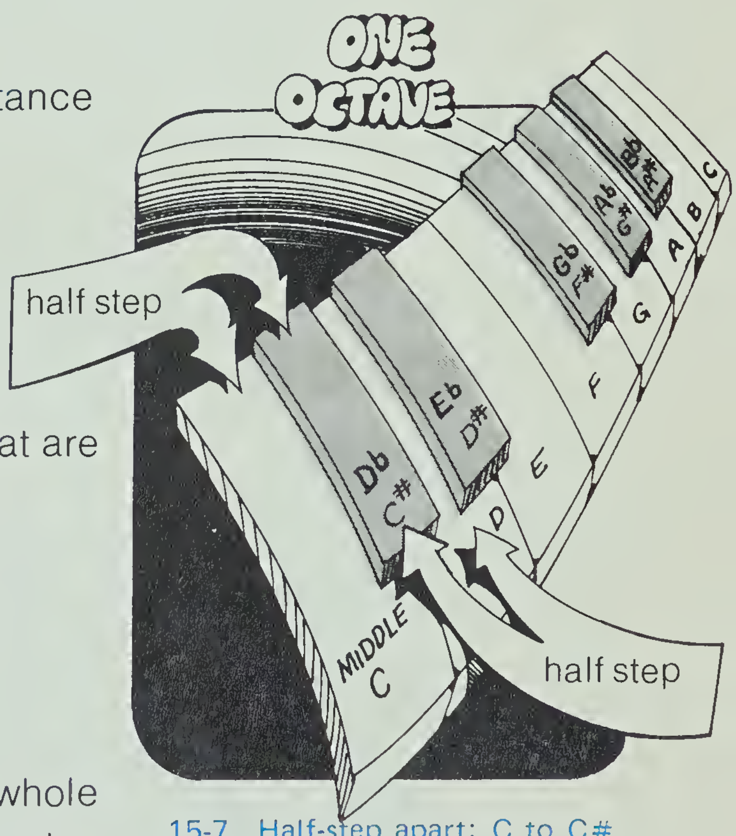
15–5. What note is a whole step higher than A?

15-5. B.

15–6. What note is a whole step lower than C?

15-6. B flat.

15–7. Using Figure 15–2 you can find examples of whole steps and half steps within the C octave. List five pairs of notes a half-step apart and five pairs of notes a whole-step apart.



15-7. Half-step apart: C to C#, D to D#, E to F, F to F#, G to G#, A to A#. Whole-step apart: C to D, F to G, G to A, A to B, C# to D#.

Figure 15–2

15–8. What are the names of 13 different notes included in the C octave? (Be sure to count both C's.)

15-8. C, C#, D, D#, E, F, F#, G, G#, A, A#, B, C.

SCALES

Figure 15–3 shows the notes from two octaves of a piano keyboard, starting with Middle C on the left. The names of the black keys (C#, D# . . .) are written in between the names of the white keys (C, D . . .). Each note in Figure 15–3 is one-half step higher or lower than the ones next to it.

Four different scales are shown in Figure 15–3. There are eight others not shown.

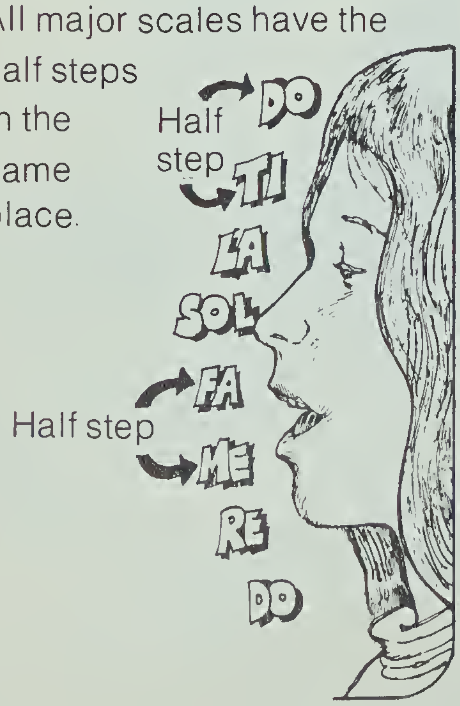
Notice that the notes of the scales have do-re-mi-fa-sol-la-ti-do written under them.

FOUR MAJOR SCALES

	C	D♭ C#	D	E♭ D#	E	F	G♭ F#	G	A♭ G#	A	B♭ A#	B	C	D♭ C#	D	E♭ D#	E	F	G♭ F#	G	A♭ G#	A	B♭ A#	B
C major scale	do		re		mi	fa		sol		la		ti	do											
F major scale (flat key)						do		re		mi	fa		sol		la		ti	do						
A major scale (sharp key)										do		re		mi	fa		sol		la		ti	do		
D major scale (flat key)			do		re		mi	fa		sol		la		ti	do									

Figure 15–3

All major scales have 8 notes. All major scales have the half steps in the same place.



The notes on the three scales don't match up, but each scale is one octave long. The two "do" notes are an octave apart. Can you see the pattern that each scale follows? (Hint: Look at the order of whole and half steps in each scale.)

major scale: E to F, B to C   A major scale: C# to D, G# to A

15–9. To see the pattern more easily, find all the half steps appearing in each scale in Figure 15–3.

major scale: A to B♭, E to F   D major scale: F# to G, C# to D

15–10. Name the notes in the G major scale.

G, A, B, C, D, E, F#, G.

15–11. Name the notes in the E major scale.

E, F#, G#, A, B, C#, D#, E.

Point out that all major scales have eight notes, each a whole step from the next, except for Notes 3 and 4 (mi and fa) and 7 and 8 (ti and do). Knowing this relationship, students can write the notes in any major scale.

Two or more notes that sound pleasant together

Three or more notes used in a combination

HARMONY

15–12. The major chord for the C scale is made up of which notes? 15-12. C, E, G.

15–13. What are the frequencies of the notes C, E, and G?
15-13. 262, 331, 392

There is a mathematical relationship between the frequencies of these three notes. This relationship is not found between other combinations of three notes. Notice what happens when you compare the frequencies of these three notes.

$$\left.\begin{array}{l} C = 262 \\ E = 330 \\ G = 392 \end{array}\right\} \text{divide each by 66 to reduce to smallest terms} \quad \left.\begin{array}{l} = 4 \\ = 5 \\ = 6 \end{array}\right\} \text{A VERY SPECIAL RELATIONSHIP}$$

Since a tempered scale is being used, the ratio does not come out on an even 4-5-6.

The 4–5–6 relationship of frequencies is the same for the major chord for each scale.

15–14. Use the frequency information in Figure 15–1 to find out the frequency relationship of the notes of the major chord for the D scale. (Major chord=1st, 3rd, and 5th note of the scale.)
15-14. D, F#, A (294, 373, 440): Dividing by 73, the relationship is 4.0, 5.1, and 6.0.

excursion

Activity 16 Planning

Activity 17 Page 69

DECIBELS

Noise, noise everywhere, and not a place to think! But would it be better if it were absolutely quiet? Just how noisy is everyday life anyway? You'll find out how much noise is made by many common objects in this activity.

Activity 18 Page 76

AND THE BEAT GOES ON

Most of what we call music has a definite beat, or rhythm. This activity may not teach you to dance, but you should be able to find the beat to a piece of music when you're finished!

ACTIVITY EMPHASIS: A description of how noise levels are measured in decibels, a listing of the sound level of noises found in different environments, and the effects of long exposure to loud noises.

Decibels

Do you know people who want to "return to nature"? They're probably looking for a little "peace and quiet." The modern world—which gives us so much comfort—is also the noisiest!

Why would anyone care about noise? For one thing, it gets on your nerves. Noise is irritating!

In fact, studies show that noise affects people in at least three ways:

1. Listening to loud noise for a long time can destroy part of the inner ear. This causes loss of hearing.
2. Loud bursts of noise lessen people's ability to do certain jobs.
3. Noise is harmful to your health—both physical and psychological.

People respond to sound very differently. One person's music is another person's noise! So how can you settle an argument about how loud a sound is?

MATERIALS PER STUDENT UNIT

None.

There is an instrument that measures the loudness of sounds. It is called a *sound meter*. There are various kinds. But all sound meters work about the same way, as shown in Figure 17–1.

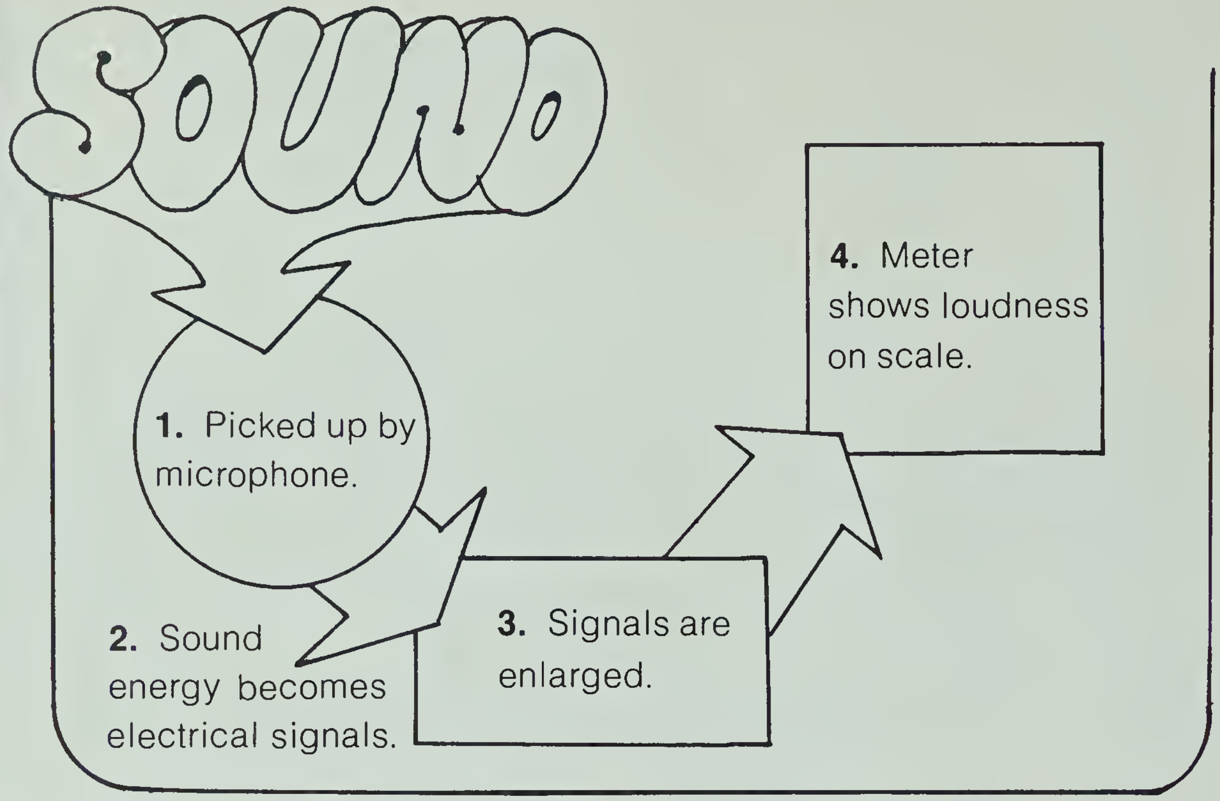


Figure 17–1

The decibel (dB) is derived from the unit of sound level called the *bel*. The bel was named in honor of Alexander Graham Bell, who invented the telephone in 1876.

A sound meter measures the loudness of a sound in *decibels* (dB). The higher the number of decibels, the louder the sound is. The decibel scale, however, is not like the metric scale you use for measuring length. If you add two objects, each 2 cm long, you get 4 cm. But if you put two sounds together, each 60 dB, the total is not 120 dB, but 63 dB!

Does this seem strange to you? Look at it this way. If you add 60 dB to 60 dB you're really multiplying the sound intensity by "2." In multiplying sound intensities, you *add* a certain number of decibels, as follows:

The decibel unit is based on a logarithmic scale. That's why multiplying decibels results in addition.

When you multiply by 2, add 3 decibels.
When you multiply by 4, add 6 decibels.
When you multiply by 8, add 9 decibels.

Do you see the pattern?

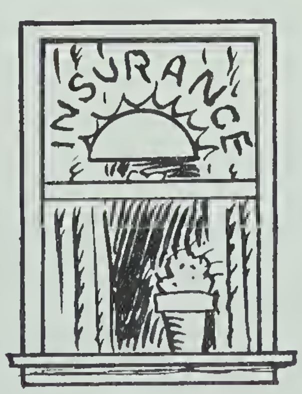
Because sound meters are expensive, your school may not have one. But if there is one around, check some of the noise levels given in Figure 17–2.

Figure 17–2 shows the noise levels in decibels for many everyday events. Figure 17–3 shows how different noise levels affect people.

SOUND LEVEL OF NOISES FOUND IN DIFFERENT ENVIRONMENTS

dB LEVEL	NOISE
0	
10	Normal breathing
15	Leaf rustling
20	
30	Soft whisper 1.5 m away
40	
50	Private office, light traffic 30 m away
60	Large, busy store, conversation at normal level
70	Car passing at 100 km/h, 8 m away Inside sports car moving 80 km/h
80	Diesel truck moving 65 km/h, 15 m away
90	Motorcycles, 7 m away Inside subway car going 55 km/h
100	Farm tractor, jet flying over at 300 m
110	Hard rock band
110–120	Jet takeoff, 60 m
130	Emergency siren, 30 m away
140	Drag strip, near starting line
150	Rifle blast


30 Soft whisper



50 Private office


80 Diesel truck


120 Jet takeoff

Figure 17–2

PEOPLE AND NOISE

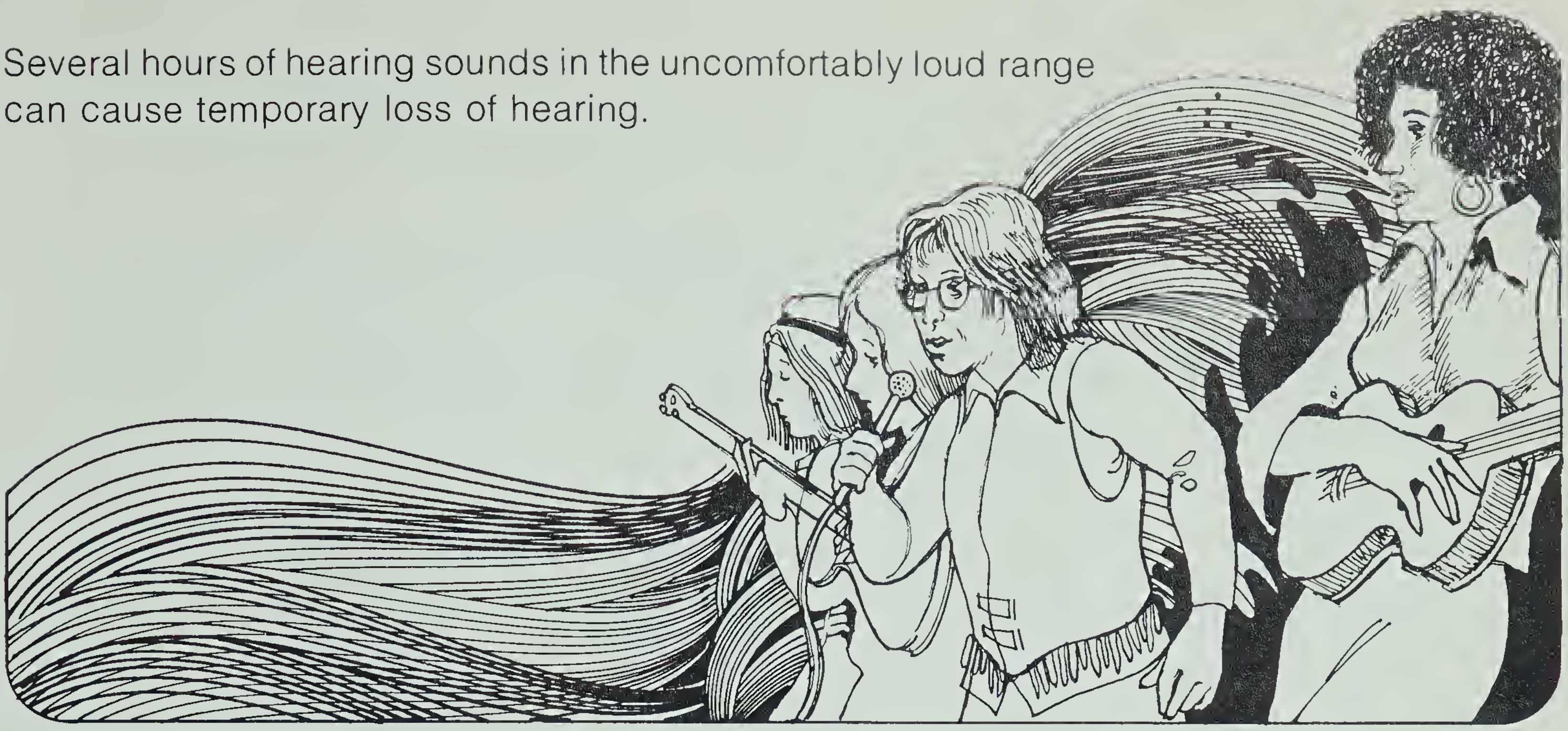
dB LEVEL	EFFECT ON PEOPLE	DESCRIPTION OF NOISE LEVEL
0	Just barely noticeable as sound	
10	Just audible to a person with good hearing	
20	Softest sound the average person can hear	
30		Very quiet
40		
50	Mild annoyance begins	Quiet
60	Normal speaking conversation level	
70	Comfortable conversation impossible	
80	Noticeable annoyance develops	
90	Hearing can be damaged if noise is continuous. Work efficiency decreases.	
100		Very loud
110	Noticeable ear discomfort	
120	Probable permanent hearing loss	Uncomfortably loud
130	Strong "tingling" sensation in ear	
140	Sharp pain in ear	

Figure 17–3

The American Academy of Ophthalmology and Otolaryngology is concerned with healthy seeing and hearing. This group suggests that certain workers wear ear protectors. These include people who must listen to 85 dB or more of steady sound more than 5 hours a day. 17-1. Motorcycle or drag strip official; jet maintenance crew at the airport; hard rock musician; rifle range trainer.

★ **17–1. What kind of workers associated with activities in Figure 17–2 should wear ear protectors?**

Several hours of hearing sounds in the uncomfortably loud range can cause temporary loss of hearing.



★ **17–2. What sounds listed in Figure 17–2 could lead to a temporary loss of hearing?** 17-2. Motorcycle and subway car sounds; farm tractor and jet noises; hard rock band.

Years of exposure to very loud sounds for several hours a day can lead to permanent hearing loss.

✔ 17–3 What jobs or hobbies can you think of where hearing could be damaged by excessive loudness? 17-3. Answers will vary. Hard rock musicians and jet crews could be affected.

✔ 17–4. Have you ever experienced a sound that was annoying? Uncomfortable? Painful? 17-4. Answers will vary.

Sounds of 160 decibels can cause total deafness. Sometimes the eardrum tears and sometimes the organ of Corti in the inner ear is damaged.

✔ 17–5. Would any single one of the sounds mentioned in Figure 17–2 or 17–3 cause total deafness? 17-5. No.

Believe it or not, sometimes noise is deliberately created! Some office buildings have been built so well to cut down on noise that people who work there have trouble getting used to quietness. Then when a phone rings, everyone jumps. Background sound is often used. The sound is piped through air-conditioning ducts to create a comfortable sound level.

Restaurants often use soft piped-in music. The music covers up the sounds of conversation and the clatter of dishes.

✔ 17–6. Name some places you've been to where background noise was added. 17-6. Answers will vary. Doctor and dentist offices and supermarkets might be listed.

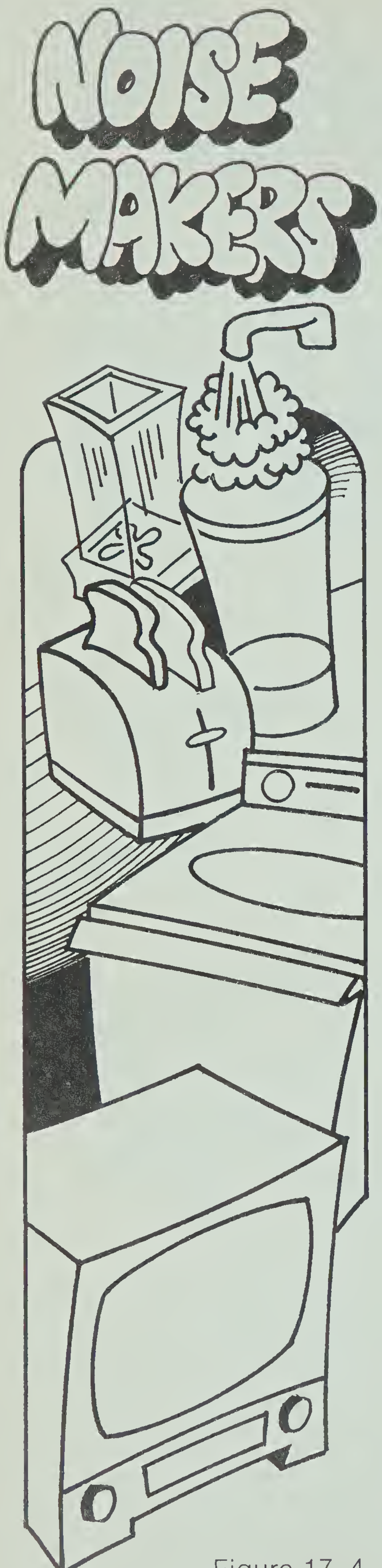


Figure 17–4

At the same time that appliances have made household jobs easier, they've made our homes more noisy. Figure 17–4 shows average decibel levels of some household appliances.

✔ 17–7. Which room of most homes is likely to have the most noise producers? 17-7. Kitchen.

✔ 17–8. Which room of your house is the noisiest?
17-8. Answers will vary.

SOUND LEVEL OF HOME APPLIANCES

dB level	HOME APPLIANCE
0	
10	
20	
30	
40	Refrigerator
50	
60	Washing machine, air conditioner, clothes dryer, sewing machine
70	TV-audio, dishwasher, portable fan, hair dryer, water faucet
80	Shower, vacuum cleaner, electric can opener, garbage disposal, electric mixer
90	Electric blender
100	Furnace blower
120	
130	
140	
150	

Noise that is made inside one room is pretty easy to keep down to reasonable levels. Much of the sound in a room can be "soaked up" or muffled by rugs, draperies, and acoustical tile ceilings.

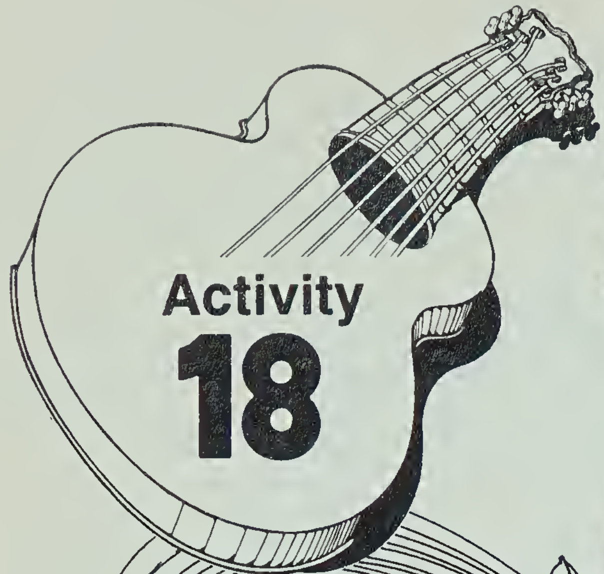
Unfortunately, sound mufflers don't keep the noise from leaving the room. If you've lived in an apartment building or large project, you know what happens. Sounds from one family's life drift over to the next-door neighbors. Or to the neighbors above and below the apartment.

✔ 17–9. Which would annoy you most: hearing sounds from your neighbor's apartment or knowing that your neighbor can hear sounds from your apartment? 17-9. Answers will vary.

✔ 17–10. Which noises that occur fairly often in your life would you like to see cut down or stopped? 17-10. Answers will vary.

✔ 17–11. Are there any sounds that you would like to have occur more often in your life? What are they?
17-11. Answers will vary.

ACTIVITY EMPHASIS: Students listen to a sound tape and classify the type of beat of various musical selections.



And The Beat Goes On . . .

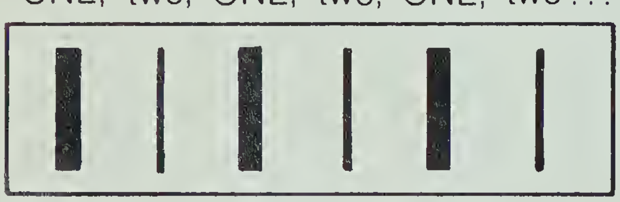
For this activity you will need these items:

cassette tape for *Sounds of Music, Activity 18*
cassette tape player

MATERIALS PER STUDENT UNIT
cassette tape for *Sounds of Music*
cassette tape player, preferably with headphones

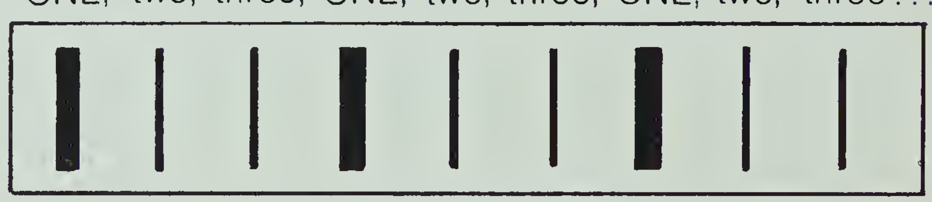
Figure 18–1 shows you how to mark down the beat as you hear it on the tape. Draw a heavier line for each note that is accented.

ONE, two, ONE, two, ONE, two . . .



Two-count

ONE, two, three, ONE, two, three, ONE, two, three . . .



Three-count

Figure 18–1

The terms "beat" and "rhythm" are sometimes used interchangeably. Beat is the recurring pulse determined by the time signature. Rhythm represents the pattern of time values shown by the notes.

✔ 18–1. Listen to the tape. What is the beat of Song 1? Song 2? Song 3? Song 4? 18-1. Two beat. Three beat. Two beat. Three beat.

Listen to some pop songs on records or on radio. Find two songs with different beats.

✔ 18–2. Which songs did you select? What are their beats? 18-2. Answers will vary.

GHIJ 085432
Printed in the United States of America

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SOUNDS OF MUSIC

ANNOTATED TEACHER'S EDITION

Ginn and Company

A Xerox Education Company

D39485

ISBN 0-663-33590-6